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SUCCESSFUL MANAGEMENT OF POLLUTION CONTROL PLANNING

William James
Editor

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SUCCESSFUL MANAGEMENT OF POLLUTION CONTROL PLANNING

Ontario Ministry of the Environment
Workshop on the Successful Management of
Pollution Control Planning
Toronto, April 25-26, 1988.

William James
Editor.

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PREFACE

Nars Borodczak

In the year since the first pollution control planning (PCP) seminar, held in Toronto on February 9-10, 1987, the Ministry of the Environment (MOE) has made many significant strides towards providing a better environment. It has released a comprehensive discussion paper on air pollution control, promoted improvements in waste management, and undertaken the ambitious task of developing regulations under the Municipal Industrial Strategy for Abatement (MISA) programme to reduce and ultimately eliminate the release of persistent toxics in effluents discharged to our water environment. All of these programmes are being superimposed on some already good environmental control programmes in Ontario.

Ontario has some 400 sewage treatment plants (STP) in operation throughout the province, 90% of which provide secondary treatment or equivalent. There are many thousands of miles of sewers conveying sanitary wastes to the treatment systems or providing the necessary conduits to carry storm water away from built-up areas for discharge to appropriate lakes, streams or rivers. These systems are proof positive of acceptable past programmes and are a tribute to the record of achievement shown by engineers, scientists, and consultants, working with municipal and provincial government officials.

In spite of successes in the past, water pollution is still a major issue with new, emerging challenges. Ontario's programme in this area has become more complex and sophisticated as the province moves towards the control of toxics under the MISA programme. If we consider the toxic materials that are released from industries to sanitary sewers, combined sewer overflows take on a new significance in terms of their impact on a natural receiver. Now that sanitary wastes, for the most part, are being adequately handled, stormwater discharges are being identified as new areas of concern.

Within the last 20 years Ontario has become more urbanised and the public has become more conscious of environmental concerns. As a result of improvements in our life styles due to a more prosperous economy the public has gained more leisure time. This leisure time is devoted to seeking out recreational outlets, putting a greater strain on our beaches and our out-of-doors. This leisure time has also provided the public with the opportunity to learn more about the environment, and how their environment is being impacted by man's activities. This sophisticated public is looking in part to the municipal engineers and is holding them responsible for their environmental well-being, since these municipal engineers are the professionals and are the managers of municipal infrastructure systems.

Traditionally the main business of municipal engineers was to deal with municipal infrastructure systems by constructing services such as sewage treatment plants, sanitary sewers, and storm water drainage systems. Efforts were undertaken to prevent basement flooding, and to provide for treatment of sanitary wastes and any other necessary service to support urban growth.

Although these efforts were very successful and acceptable in the past, new concerns brought new challenges and will bring about changes on how business is to be carried out by municipal engineers, scientists, consultants, and municipal and provincial government officials. Because new problems will become more complex, pollution control planning will have to become an integral part of any remedial strategy to be undertaken.

More and more municipalities are becoming involved in pollution control planning to identify problems and develop appropriate solutions. We have fine examples in St. Catharines in the Niagara Peninsula, North Bay in northern Ontario, and the remedial work undertaken in the eastern beaches area of Toronto. Participation by more municipalities is necessary to obtain appreciable progress on a province wide basis. Expanding their role to encompass pollution control planning will give more challenges and opportunities to municipal engineers, scientists and consultants, and in return, bring a sense of gratification from municipal councils and the citizens of Ontario.

As the role of municipal engineers expands so will the role of consultants who may have to divert some of their energies from the more conventional practices of designing subdivisions, sewage treatment plants and flood control facilities to undertaking planning and cost benefit assessments before recommending technical corrective measures. Even educational institutions which produce excellent engineers and scientists will have to develop graduates familiar with many disciplines and capable of melding these disciplines into one pollution control strategy. Municipal and provincial government officials will have to look at the greater picture before committing funds for a project to ensure that these projects are part of a bigger solution and are being implemented according to an established priority.

The organization of this pollution control planning seminar is the Ministry's contribution to technology transfer. The theme - *Successful Management of Pollution Control Planning* - was chosen with the belief that a challenging undertaking such as pollution control planning requires strong leadership: leaders who will inject enthusiasm and provide guidance to pollution control planning; leaders who will educate newcomers and novices on their teams on the challenges that lie ahead. This seminar has been designed to contribute, in a small way, to leadership development in pollution control planning.

We are all aware that a seminar alone cannot generate widespread enthusiasm for pollution control planning among professionals, nor will it build up expertise overnight. The success of passing on the technology and interest in pollution control planning to your teams and to others will depend upon and come from individuals like yourself.

CHAPTER 1

Successful Management of Pollution Control Planning: Purpose and Implications

William James

In this chapter the background, purpose and aims of this book are presented, and then the actual contents are briefly reviewed. Evidently, the new procedures herald an important change in environmental engineering, and the implications of these changes are discussed in more detail.

1.1 PURPOSE OF THIS BOOK

This book is the second in a series. Like the first, it comprises papers presented at a symposium financed by the Ontario Ministry of the Environment (MOE) pollution control planning studies program. Under the program, the MOE provides financial and technical assistance to all municipalities in Ontario for the development of municipal pollution control plans (PCP's). In this book, an emphasis is placed on protection of beaches against pollution. The book describes how to plan and subsequently achieve and maintain a high quality environment, including air, water and land, one that protects human health and the ecosystem, and contributes to the well-being of the people of Ontario. For our purposes the *environment* is simply *our surroundings*, and may be catchment-wide or local in scale, depending upon the issues.

PCP studies were first initiated in 1985. At the time of this symposium, April 1988, there were about eighteen proposed and approved PCP studies across Ontario, in addition to a number of studies in the Metropolitan Toronto area. The annual budget for PCP studies was about $1.3 million. An individual PCP study may cost $1.0 million, and may take about 30 months to complete.

CHAPTER 1

A PCP is a comprehensive plan for the remedy of water pollution in the municipality. In the PCP development process, all major pollution concerns are addressed, such as beach pollution, sewage treatment plant (STP) bypasses, and combined sewer overflows (CSO's) to receiving water bodies. All major pollution sources from storm sewers, sanitary and combined sewers, STP effluents and industrial discharges are investigated. Rigorous analysis is stressed and computer modelling or simulation is almost invariably an important part of the PCP development process. Planning techniques such as evaluation of alternative solutions and trade-offs are used in the formulation of the package of remedial measures. The PCP is source-specific and location-specific, and lists not only remedial measures, but their estimated costs and the results of an assessment of their feasibility, implementability and potential benefits. In other words, the information from the PCP should be sufficient for seeking approval for implementation of the plan, and provide the basis of detailed design of the best remedial measure.

As a primer for successful management of a PCP study, this book describes all facets of the study that are important to the project manager, such as skills, ideas and methods. The book is aimed at professionals who seek to manage a PCP study successfully, from the inception of a study to implementation of the completed pollution control plan. Such professionals include PCP co-ordinators, reviewers and advisers, key MOE and municipal officials responsible for area-wide management of water pollution, and consulting engineers. Successful managers should be able to assess the technical merits and needs of PCP study activities; to compete for resources, priorities and approvals; and be able to take a leading role in the planning of the study and in the formulation of pollution remediation. The book is well illustrated with practical examples providing insights and experiences from leading professionals, and useful technical information for making management decisions.

The preliminary literature for the symposium listed some of the practical information covered, including:

1. the benefits of PCP compared with traditional approaches;
2. ways a PCP study may be guided to achieve the study goal;
3. the best use of modern pollution control planning techniques;
4. what to co-ordinate in a PCP study, e.g. how to recognize irrelevant and trivial pursuits and remove them from the study plan;

5. how to communicate with the study team, steering committee and the public about the PCP study;
6. selection of the right kind of pollution information to meet study needs;
7. how to develop a sampling and monitoring field program;
8. management of the voluminous sampling and monitoring data;
9. coping with difficulties arising from lack of experienced staff; and,
10. hiring competent consulting engineers and getting them to do a good job.

Furthermore, evaluation and development techniques for PCP studies that are covered in this series of books include the following:

1. why wet-weather flow and modelling are so important;
2. how far to trust models and modelling;
3. how to interpret data and results of analysis;
4. how to use pollution control criteria in the planning process;
5. how sewer rehabilitation studies will help save sewer servicing costs;
6. how to make constructive use of critiques and peer reviews; and,
7. how to assemble the final PCP, and ensure its marketability and implementability (i.e. how to get the plan implemented and not shelved).

A brief review of each chapter is presented here.

1.2 SUMMARY OF CONTENTS

In Chapter 2, **Dormer** outlines the MOE's *lifelines grant program*, which comprises: (1) pollution control planning studies, (2) infrastructure needs studies; and, (3) rehabilitation implementation. The *needs study* is the cornerstone of the infrastructure rehabilitation program, and should identify the most cost-effective long-term solution.

In Chapter 3, **Wong** states that the aspiration of Ontarians is for further improvement to the water quality of the province's water resources, particularly its recreational waters and beaches. For this aspiration to be realized, he states that a new technical approach to

pollution control is needed: the PCP recognises the fact that pollution control is no longer synonymous with sewage treatment. Pollution control must necessarily contend with multiple pollution sources, water-use interests, and professional disciplines. This point is developed further later in this chapter. The MOE provides grants to municipalities for the development of PCP's for their jurisdictional areas, if they follow the MOE's general terms of reference and technical guidelines. The product of a study undertaken with a MOE grant should be a PCP which is comprehensive, coordinated, incorporates the best solutions and is implementable.

Heathcote suggests in Chapter 4 that the first question to be asked in the preparation of a PCP is: *what is the problem?* The answer forms the basis for a program of pollution measurement and remedial action, and indeed for the entire PCP. In general, a *problem* can be defined as an impairment of a desired or beneficial water use, such as: (1) drinking water, (2) swimming and bathing, (3) aquatic life habitat, (4) agriculture (specifically, livestock watering and irrigation), (5) industry (specifically, process and cooling waters), and (6) other uses such as fire protection, navigation, and power generation, which tend to be less sensitive to water quality.

The MOE's municipal/industrial sewer abatement (MISA) program, writes Heathcote, heralds a new era of pollution control regulation in Ontario. The data collected through the effluent monitoring priority pollutant list (EMPPL) and MISA screening programs will provide the MOE with an increasingly large body of information about the toxicity of pollutants, their presence in industrial and municipal effluents, and their loadings to receiving waters in Ontario. These data will help water managers to determine what, how and where to measure in receiving waters. Heathcote explains how the growth of MISA and EMPPL will spur better laboratory protocols (for detecting and quantifying low-level chemicals in water), better detection capability, more accurate knowledge of effluents, an improved ability to define desirable levels of pollution control.

Kennedy and Zukovs state in Chapter 5 that the objectives of a PCP study are to:

1. define the cost-effective, environmentally and socially acceptable measures which will achieve the necessary levels of control over water-borne pollutant discharges from municipal, industrial and agricultural sources, in order to protect beneficial water use;

2. provide a framework which will facilitate municipal, industrial and

agricultural pollution control planning and enable a greater degree of integration with other municipal planning and contemporary water management and planning processes; and,

3. enable the MOE to make optimum allocation of capital funds for assisting in the provision or upgrading of municipal wastewater conveyance and treatment facilities and drainage works.

To meet these objectives, they continue, an assessment provides the basis for formulating alternative pollution control plans. To assess the alternative plans, evaluation criteria are established, which address five general categories: water quality (ambient and/or effluent), economic, financial, environmental impact and social impact. The entire PCP process is documented in a *summary report,* which explains in detail the methodology behind the selection of the *best* plan, the plan itself, and outlines the implementation of the plan.

In Chapter 6, **Medina** writes that urban stormwater runoff processes can be subdivided into three major subsystems: overland flow, storage and conveyance through natural or engineered drainage systems to receiving waters. Medina further describes (1) quantitative analysis of the rainfall time series that generates the runoff events, (2) overland flow, pollutant accumulation and washoff, and (3) storage and transport through natural or engineered devices; reviews the role that mathematical models play in the development of urban pollution control plans, presents examples of opportunities to combine the advantages of both physically-based and statistically-based approaches into a single application, and concludes that simulation models are particularly useful in *evaluating alternatives.*

In Chapter 7, **Henry and Kennedy** state that the key to developing a sound monitoring and sampling program (MSP) for a PCP study lies in answering the following questions: (1) why is a monitoring and sampling program to be conducted? (2) what should we monitor and sample? (3) where should the monitoring and sampling take place? (4) when should the monitoring and sampling take place? (5) who should do the monitoring and sampling?

A MSP is conducted if it is necessary to collect additional information in order to carry out the following tasks:

1. calibration and validation of specific pollutant models;
2. definition of specific cause and effect relationships;
3. characterization of pollutant sources; and,
4. definition of stochastic/statistical relationships.

Monitoring and sampling is conducted primarily in three locations: in-sewer, in stream, and nearshore (beach) areas. The MSP generally collects data in four time ranges: daily, one to four hours, continuously, and periodically. The time frame selected is based upon the site location and the amount of data that is needed to fulfil the requirements of the model. Three levels of staff are required to carry out the program: field supervisor, field technician and samplers. The process of hiring staff is the responsibility of the agency conducting the PCP study.

Finally, in Chapter 8 **Leppard** shows that there are many different ways to involve the public, and never enough time or money to do it properly. Any project will benefit from citizen involvement - because it's their community, their money and their future. As more and more planning processes are subject to the intense scrutiny of the taxpayer, flexible and creative ways to harness their energy and resourcefulness must be incorporated into the process.

The writers repeat one theme: *the old approaches to pollution control must be changed!*

1.3 IMPLICATIONS: THE NEW ENVIRONMENTAL ENGINEER

In presenting for practitioners the methodology of a successful PCP, this book illustrates how emerging social and environmental values contribute to successful PCP's. The book is a handy reference for dealing with questions other than technicalities, e.g. environmental impacts, public involvement, and accountability, especially for disruptive projects. The book therefore sets a new Ontario standard for professional environmental engineering in the 21st century.

To be successful, pollution control planning must not only follow official procedures, but its scope must be area-wide and multi-jurisdictional. Moreover it must be sensitive to the requirements of *all* stakeholders. Satisfying all such concerns is clearly difficult, if not impossible. Certain imbroglios plague the planning process at practically every step: the complex interplay of various (sometimes conflicting) political policies; complex and controversial cause-and-effect ecological relationships; dated legislation and unequal enforcement procedures at manifold levels of government; and the

often emotional debate between local economic needs on one hand and environmental aspirations of various sectors of the public on the other. The half-lives of these complexities are both long and short compared with the duration of the planning process itself. For the plan to reach a state of finality such that implementation can be at least considered, compromise is essential. This compromise is the modified "success" that can be termed *"successful management"*, the focus of this book.

Successful management of pollution control planning will surely challenge environmental engineers well into the future. A practical manual for contemporary practitioners is of course necessary; it is also difficult because current practitioners were necessarily educated in earlier, less environmentally aware times, tied to curricula that were largely unrelated to present-day issues. In any case, in a period of such rapid change, curricula are bound to be out-of-date by the time the faculty can even agree on the academic objectives.

For the remainder of this section, I am indebted to an article by A.J. Fredrich.

Like other specialty areas, knowledge in the field of environmental engineering can be subdivided into the following broad categories: **philosophy, policy, process** and **problem-solving approaches**. Each category must be studied by modern environmental engineers.

In his paper *Educating Environmental Engineers for the 21st Century* (Universities Council on Water Resources, Spring 1990) Fredrich states, *"The study of relevant **philosophy** is one of the weakest parts of undergraduate engineering education in all specialty areas, but in no other area is it as debilitating as it is in the field of environmental engineering. Other professionals with far less understanding of effective problem-solving approaches often have a far greater understanding of the fundamental environmental issues and concerns than engineers have."*

Paraphrasing Fredrich: many environmental engineering courses include at least a superficial review of relevant federal, provincial and local legislation. However, such information is almost always limited to a description of how law enforcement affects engineering analysis. What we need rather, is an understanding of **policy**, i.e. the conditions and circumstances that produced the legislation: of why a particular set of standards or practices is mandated, and why other equally plausible, and perhaps superior,

approaches are ignored; and how successive legislative acts and policies in a given field are related to one another and to other acts and policies in other related areas. This is the stuff of general environmental philosophy. Without this knowledge the engineer is severely handicapped in understanding why a particular problem-solving approach is preferred.

Process is what transforms policy to problem solving. In environmental engineering, process includes planning, public involvement, social and environmental impact assessment, economic and financial feasibility evaluations, budgeting and financing projects, and even elections and referenda. Few, if any of these topics get any significant treatment in today's engineering curriculum. Fredrich observes that *"Even as basic a process as planning, which underlies every civil engineering project of any size, is given such cursory treatment in civil engineering curricula that there is today no well-known textbook on civil engineering planning."*

Problem solving is, of course, the one area where we are strong. Our graduates generally understand and employ appropriate techniques to analyse common environmental problems. But, without the knowledge of philosophy, policy and process needed to underpin their problem-solving abilities, engineers are relegated to a role of technician.

1.4 CONCLUDING REMARKS

What, then, are the pre-requisites for the successful PCP manager? First of all we must add to the environmental engineer's expertise as a problem-solver, skills such as environmental ethics and philosophy. PCP managers must not only have studied Rachel Carson, Barry Commoner and their genre, but *believe* in their ethical positions. Secondly, deep understanding of *democratic environmental process and procedure.* This entails society's accepted practices for public debate; procedures for establishing party and political policy; legislation processes and legal precedents; environmental law; local, regional, provincial, federal and international agencies involved and their enforcement practices; public participation and conflict resolution; and requirements for monitoring and compliance. Not many of our former managers of pollution control planning had all these qualifications. And of course we have experienced many mistakes in the past. The point of this review of the background preparation of an environmental engineer is to show that

avoidance of the old mistakes is a major difficulty. We must come to terms with the fact that many past designs, shown at the time to be the best or optimum engineering solution, were and continue to be *not even acceptable* societal solutions. We may have failed to master an appreciation of social values or to embrace the societal duties of an environmentally responsible, well-informed citizen.

According to Fredrich, "nowhere within the field of civil engineering has the need for change been more obvious than in the environmental engineering specialty. And nowhere else have the demands for change been more insistent. Admittedly, some changes have occurred. The course we once called *Sanitary Engineering* has been relabelled *Environmental Engineering*, and it now includes discussion of air pollution and hazardous waste disposal in addition to water pollution and solid waste disposal. It doesn't begin to address the larger problems faced by today's practicing environmental engineer, and it is wholly inadequate to meet the needs of the environmental engineering of the 21st century."

There can be little doubt that a new paradigm for environmental engineering will be necessary for the nineties, and that the PCP methodology developed by the MOE will promote that change. New methods are essential because of emerging societal sensitivities to environmental issues. Modern (as opposed to future) Canadian engineers are more environmentally sensitive, and less likely to support traditional attitudes, than their predecessors. Engineers of the future will have radically different skills, moving easily across many disciplines, and communicating confidently with informed advocacy groups. A new kind of renaissance engineer will be needed in the 21st century, when regional community environmental standards will be exacting.

There is a need for distinctly new ideologies in environmental engineering, for example: ecosystem awareness, environmental ethics, policies and assessment, respect for nature, sustainable development, ecology, and long-term system-wide impacts. This focus consciously goes beyond traditional sanitary engineering, which concentrates on chemical-mechanical processes of treatment of industrial and municipal wastes; the new focus deals with issues related to energy reduction; materials recycling; products reuse; resource recovery; and environmental ethics, policy, enforcement and legislation.

The new paradigms must eventually accord with the projected objectives of the federal government's recently-announced Green

Plan. The newly published *Framework for Discussion on the Environment* (1990) outlines the Government's broad approach to environmental problems and suggests specific issues that need to be addressed as it develops its *Green Plan*. The *Framework* admits that achieving sustainable development will not be easy. It will require changes in our attitudes and behaviour towards the environment. Indeed, environmental considerations will have to become a forethought, not an afterthought, in the decision-making process.

Priscoli (1990) asks the rhetorical question: So what is the difference between old and new environmental engineers? In response he states that clearly the new environmental engineer is not simply a retreaded old sanitary engineer, but seeks to bring environmental concerns into the design phase of engineering with new understanding of goals of health and development.

New environmental engineering has been succinctly covered in a recent article *Becoming Environmental Engineers for the Nation and the World* by Priscoli.This chapter may be concluded elegantly by abstracting several paragraphs from his paper. He writes, "Publicly, we must move from standards to guidelines or principles. In philosophical terms, this means moving from absolutist to utilitarianism as the basis of policy making. We should be moving to blending our public health absolute preservation and our conservative utilitarian traditions. Accountability, performance and power sharing will become part of the public ethic we must foster. As engineers, we must move even further to blending and mixing quality and quantification in our approaches."

"We must move from seeing ourselves as a set of solutions seeking application, to seeing ourselves as problem-solving capacities. We must move from defining ourselves purely as engineer constructors or designers to engineer managers and stewards. We must move from defining ourselves as manipulating things to managing systems, people and life. We must come to see our milieu not as machines, but as growing, interdependent biological entities."

"We must move from a domination idea to a nurturing idea. We must move from being observers of events around us to an understanding that we are, inevitably, participants in those events. We must view our actions in the long as well as the short term and we must decide on actions in terms of how we think the world should be."

That seems to summarize the necessary changes, and PCP is a manifestation of that change; it places this book in historic

perspective.

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CHAPTER 2

Sewer Rehabilitation Study: A Strategy for Wise Spending

Robert H. Dormer

2.1 INTRODUCTION

The mandate of the MOE is to achieve and maintain quality of the environment including air, water and land that will protect human health, the ecosystem and contribute to the well-being of the people of Ontario.

Ontario's wealth of fresh water is at risk as society produces more and more wastes and pollution as by-products of urban development. Dealing with the varied challenges to Ontario's drinking and recreational water quality requires a comprehensive, long-term approach.

During the formation of this Ministry's overall multi-year strategy it was noted that MOE had expended a considerable amount of funds on construction of new water and sewage systems over the years, but very little attention had been given to the fact that these systems will require rehabilitation or eventual replacement.

Another problem affecting the environment was the protection of the water quality at the beaches. Many beaches had to be closed to swimmers during mid and late summer because of pollution.

The result of these concerns was the development of a new grant program known as LifeLines. The program is made up of three parts:

1. pollution control planning studies.
2. infrastructure needs studies.
3. rehabilitation implementation.

Pollution control planning studies are covered in other chapters. *Rehabilitation implementation* is the construction component of this program. *Needs studies* cover the study of both sanitary collection systems and water distribution systems. This chapter concentrates only on sanitary collection system needs studies.

2.2 WHY DO WE REQUIRE A NEEDS STUDY?

2.2.1 Definition of a Needs Study

More than 80% of Ontario's population is served by communal sewage systems. This underground system which serves Ontario's towns and cities is a valuable asset. As these sanitary collection systems age, a number of factors can lead to the development of serious problems within the system.

In considering the rehabilitation of such a system, a distinction must be made between the structural condition of the pipe and the capacity of the system. A needs study does not mean a review of the design analysis of the system, but means a review of the management alternatives of the existing situation to achieve a better performing system.

The needs study is the corner stone of the infrastructure rehabilitation program; it forms the first part of the program, being followed by the rehabilitation implementation, and finally by the checking of results. If a needs study is completed properly and the most cost-effective, long-term solution is identified, then the municipality will have a clear rehabilitation program to follow in order to satisfy their needs.

2.2.2 Sanitary Sewer Problems Requiring a Needs Study

In older systems, pipes carrying human and industrial wastes to sewage treatment plants begin to crack and crumble. In dry times when water tables are low, these wastes can escape to contaminate groundwater. In wet times, when water tables are high, groundwater can infiltrate into the pipes overloading the system. This can cause pumping stations and treatment plants to be by-passed, putting partially treated or untreated sewage into receiving water bodies. Failure to correct these problems can lead to increased maintenance cost, and health and environmental problems.

In a sewage collection system, overloading of the sewage treatment plant and pumping station bypassing can be caused by either infiltration, inflow or both. The factors contributing to these conditions are both many and varied (see Figures 2.1, 2.2).

Infiltration occurs as groundwater enters the pipe system through, for example, leaking sewer pipes and manholes, and defective house connections. *Inflow*, or storm water entering the pipe system, may result from catchbasins connected to the sewer, cross connections to the storm sewer, roof leaders or sump pumps connected to the sewer, or foundation drains connected to the sanitary sewer. *Flooding of basements* can be caused by obstructions in the pipe causing a flow back-up, a collapsed sewer pipe , infiltration or roof connections. *Frequent breaks/repairs* occur through aging, vibration, or the freeze/thaw cycle. Present technology now offers a wide range of alternative methods for the physical rehabilitation of underground piping. Moreover, new techniques are being developed every day.

In the definition of "system" under "needs studies" MOE included (in addition to the mainline piping) the service connections, roof leaders, footing drains and any other physical connection to the main which contributes extraneous flows to the system. It is widely recognized that in sanitary sewer systems, effective rehabilitation must include improvements to the private side.

Figure 2.1 Reasons for infiltration in sewage collection systems

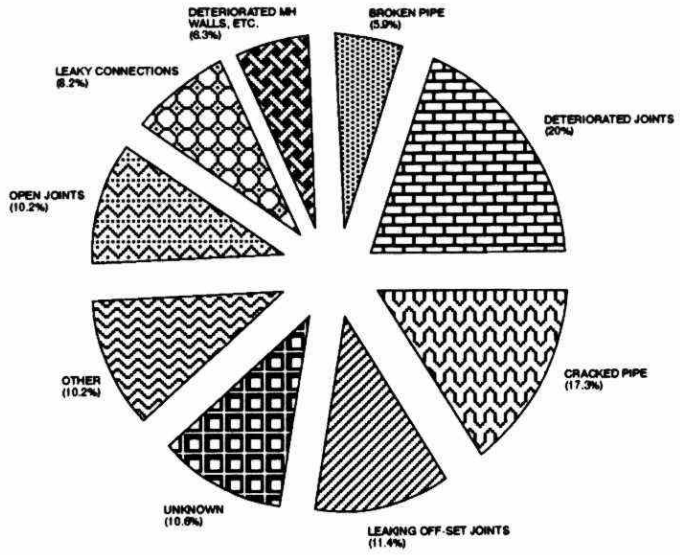
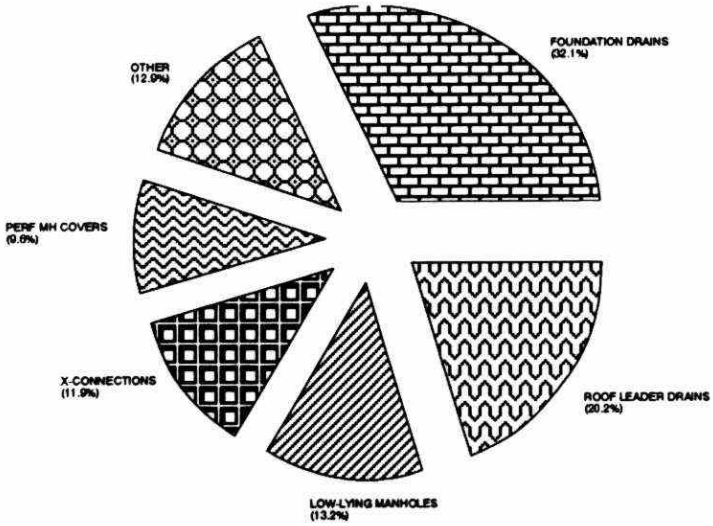


Figure 2.2 Reasons for inflow in sewage collection systems



2.3 WHAT DO WE MEAN BY REHABILITATION?

Rehabilitation is a general term to describe various activities to restore a system as closely as possible to its original condition and function. This can include *replacement* (the construction of a new watermain or sewer at the same or near the same location to fill the original function), *renovation* (the improvement of the existing condition by re-lining techniques to extend the life of the watermain or sewer), and *repair* (repairing short lengths of the structural fabric of the watermain or sewer).

2.4 ECONOMIC VERSUS FINANCIAL FEASIBILITY

A clear distinction must be made between the economic feasibility and the financial feasibility of the infrastructure rehabilitation.

Economic feasibility results from a cost/benefit analysis where the benefits are greater than the cost. Financial feasibility depends on the availability of funds to carry out the necessary remedial measures.

The analysis of economic feasibility and the review of financial feasibility are essential parts of the infrastructure needs study, necessary to prepare a viable rehabilitation implementation program.

2.5 COMPOSITION OF THE INFRASTRUCTURE NEEDS STUDY

The infrastructure needs study can be broken into five phases for a large study:

1. inventory the existing system,
2. analyze the existing system,
3. conduct tests,
4. evaluate data and alternatives, and
5. make recommendations.

During these phases, use may profitably be made of the Sewer Inventory Maintenance System (SIMS) program. SIMS was developed by the Tri-Committee made up of three parent organizations: the Ontario Good Roads Association, the Municipal

Engineers Association, and the Ontario Chapter of the American Public Works Association. Its mandate is to encourage and facilitate the use of microcomputers in public works.

A survey among municipalities was conducted to identify their needs. The result of the survey was a clear indication that a comprehensive Sewer Inventory Maintenance System was required. This became then the first of a number of projects undertaken by the Tri-Committee to provide software tailored to the needs of municipalities in Ontario.

A few months later a draft Request For Proposal (RFP) was ready. The objectives listed were as follows:

1. keep an electronic record of existing inventory,
2. maintain a preventative maintenance schedule,
3. produce work orders,
4. provide for service history,
5. provide for cost accounting, and
6. provide for data management.

When the Ministry of the Environment reviewed the RFP, it was quite clear that the Ministry and the municipalities had much in common, since the objectives of the RFP supported the MOE's infrastructure rehabilitation program initiative, which was being formulated at that time. Also, since the SIMS software development was a municipal initiative, it was the Ministry's opinion that there would be greater likelihood that it would gain acceptance by municipalities in Ontario.

Encouraged by the decisive action of the Tri-Committee and the quality of its first systems specification, MOE approved 50 per cent funding assistance, up to a maximum of $50,000 in support of the project.

In December 1987 the first beta release of the software was installed at the three test sites and the Ministry. Representatives of the three "pilot municipalities" and Mr. Willy Brink have been very active during the last three months with the testing of the SIMS software. It is expected, at the time of writing (April 1988), that this will be completed by the end of April and that the first official release of SIMS can be made in May 1988.

Fifteen municipalities are already committed to use SIMS and the author is sure that, due to its success, many more will follow.

2.5.1 Inventory of the Existing System

Phase 1 consists of the inventory of the existing system. It is at this point that the SIMS program may be usefully employed. The steps to be followed in this phase are:

1. review the "as built" drawings that are available within the municipality and extract the relevant data,
2. prepare the inventory data in a format for input into the microcomputers,
3. field check the data to ensure accuracy, and
4. input the data on the microcomputers (optional).

2.5.2 Analysis of the Existing System

Phase 2 of the needs study is to analyze the existing system. For sanitary sewers, the steps are:

1. identify the drainage areas within the municipality (large cities),
2. monitor the flows from those drainage areas to establish wet flows and dry flows (minimum 9 months),
3. compare the design flows with actual flows to identify which areas have actual flows far in excess of the design flows (if actual flows are lower than design flows then consider ending the study because there may not be a cost benefit to reduce flows more than at present), and
4. look at the repair or problem areas (basement flooding) within the municipality, identify the worst areas and concentrate effort on more detailed studies in the worst areas, where most benefit can be seen.

2.5.3 Conducting Tests

Phase 3 of the needs study would be to conduct tests on the existing systems. For the sanitary sewer, the sources of infiltration must be identified. This can be done by:

1. more detailed flow monitoring to identify the location of the problem area,
2. a visual survey of manholes to check for groundwater or storm water entering the sanitary sewer,

3. a house to house survey to identify roof leaders and sump pumps connected to the sanitary sewer,
4. dye testing,
5. smoke testing (same as above), plus test catchbasins connected to sewers, and
6. TV inspections of mainline sewer and service connections for roof connections, cracks in pipes, pipe settlements and collapses. (TV inspection is most expensive and should be the last resort unless checking for structural items).

2.5.4 Evaluating Data and Alternatives

In phase 4 the data and alternatives should be evaluated. This will include:

1. evaluating data,
2. entering the data on SIMS/WIMS computer program (and updating SIMS to centralise data),
3. reviewing the repair or problem area,
4. determining the structural integrity of the system,
5. determining the sources of inflow/infiltration,
6. reviewing the existing maintenance program,
7. reviewing the existing by-laws and their enforcement, and
8. establishing corrective alternatives.

2.5.5 Recommendations

Phase 5 concerns recommendations and should:

1. identify the costs of the various alternatives,
2. identify the most cost-effective solution (most benefit with least cost),
3. set priorities (worst areas first), and
4. formulate a multi-year rehabilitation program, based upon the most cost-effective solution, (and presumably concentrating in the worst areas first, where there will be most benefit for the costs incurred).

2.6 A TYPICAL REHABILITATION IMPLEMENTATION PROGRAM

The recommendations furnished by the needs study (part 1 of the three part program) form the basic rehabilitation implementation plan (part 2 of the program). A typical example is given in Figure 2.3.

Figure 2.3 Recommendations for a Rehabilitation Program

PART 2

REHABILITATION IMPLEMENTATION
SANITARY SEWERS

REDUCE INFILTRATION

- Relining, grouting and replacement of sewer (same size)
- Where feasible, disconnection of cross connections between sanitary and storm sewer
- Manhole grouting, replacement, installation of manhole lid inserts and installation of frost connections
- Relining, grouting and replacement of service connections
- Disconnection of roof leaders, sump pumps and foundation drains

ACCEPT INFILTRATION

- In line/off line storage tanks
- Expand treatment plant — Funded Under
- Expand pumping station — Direct Grant

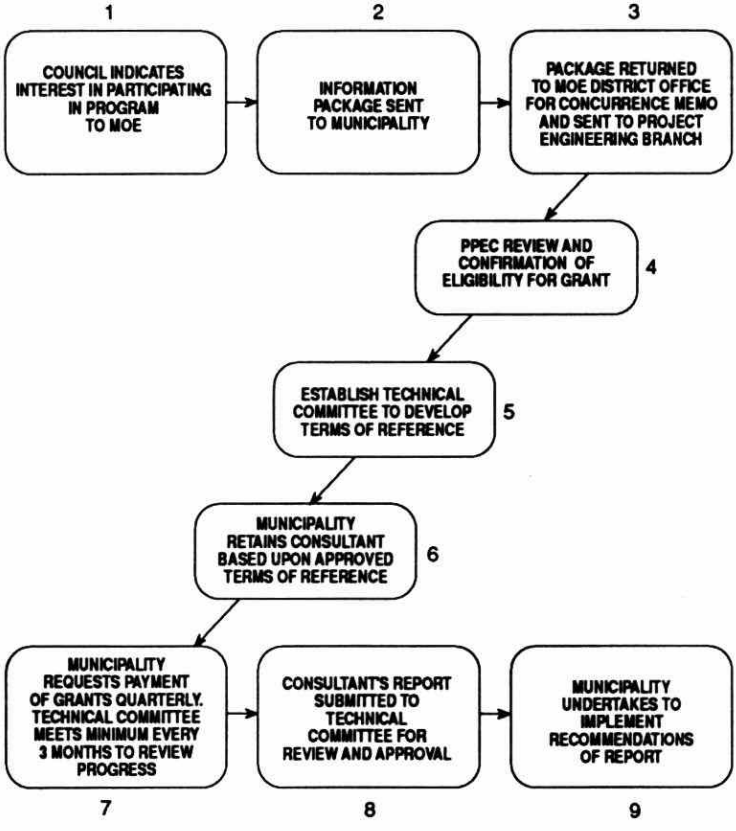
2.7 CHECK FOR RESULTS

The last step - frequently overlooked - is the check for results. To discover how effective the rehabilitation implementation plan was in reducing flows to the sanitary sewer system the results should be flow-monitored.

Again, if the municipality uses SIMS, the computer system must be maintained and updated continually, so every time someone changes a section of sewer or manhole, that activity should be entered on the SIMS Program as a record and a history of that section

of sewer. In the future when the municipality comes to MOE for a grant on replacement or rehabilitation of that sewer a simple computer printout will give the total known history of that sewer section.

Figure 2.4 Procedures for a Rehabilitation Program Needs Study


1
COUNCIL INDICATES INTEREST IN PARTICIPATING IN PROGRAM TO MOE
2
INFORMATION PACKAGE SENT TO MUNICIPALITY
3
PACKAGE RETURNED TO MOE DISTRICT OFFICE FOR CONCURRENCE MEMO AND SENT TO PROJECT ENGINEERING BRANCH
PPEC REVIEW AND CONFIRMATION OF ELIGIBILITY FOR GRANT
4
ESTABLISH TECHNICAL COMMITTEE TO DEVELOP TERMS OF REFERENCE
5
MUNICIPALITY RETAINS CONSULTANT BASED UPON APPROVED TERMS OF REFERENCE
6
MUNICIPALITY REQUESTS PAYMENT OF GRANTS QUARTERLY. TECHNICAL COMMITTEE MEETS MINIMUM EVERY 3 MONTHS TO REVIEW PROGRESS
7
CONSULTANT'S REPORT SUBMITTED TO TECHNICAL COMMITTEE FOR REVIEW AND APPROVAL
8
MUNICIPALITY UNDERTAKES TO IMPLEMENT RECOMMENDATIONS OF REPORT
9

2.8 PROCEDURES FOR REHABILITATION PROGRAM NEEDS STUDY

Any municipal council interested in participating in a rehabilitation program should follow the procedure laid down by the Ministry as shown in Figure 2.4. As a first step, the council should request the information package from MOE. This completed package must then be returned to the MOE District Office for a concurrence memo and for dispatch to the Project Engineering Branch. The Provincial Project Evaluation Committee (PPEC) will review and confirm eligibility for the grant, and a technical committee will then be established to develop the terms of reference.

The municipality may now retain a consultant upon the approved terms of reference. It should request payment of grants quarterly, and the technical committee will meet a minimum of once every three months to review progress. The consultant's report will be submitted to this committee for review and approval, and the municipality must undertake to implement the recommendations of the report.

2.9 PROVINCIAL FUNDING FOR NEEDS STUDY

The MOE will fund needs studies at a minimum of 50% for those municipalities who have 5,375 people or more. If the population is below 5,375 then a grant of between 50% - 85% is based upon a formula. If the population is under 1,000 people then the grant is 85%.

All municipalities will receive 33.33% funding from the Province for rehabilitation of works.

CHAPTER 3

Pollution Control Plan: The Key to Successful Pollution Remedy

Wan Wong

3.1 INTRODUCTION

Water pollution control has been practised in Ontario for decades and much has been accomplished. Ontario has built 400 sewage treatment plants, more than 90% of which provide secondary treatment. The efforts are continuing. Today, MOE directs grants alone for sewage capital works amount to about $70 million annually.

This level of pollution control has helped maintain the water quality of the rivers and lakes of Ontario at the present state despite substantial urbanization.

The aspiration of Ontarians, however, is for further improvement to the water quality of the province's water resources, particularly recreational waters and beaches. For this aspiration to be realised, a commitment of effort by all concerned is required. A new technical approach to pollution control is also needed.

The Ministry of the Environment is providing leadership in both areas. MOE grants are made available to municipalities on application for the development of pollution control plans for their jurisdictional areas. General terms of reference which enshrine a new technical approach, have been developed to provide technical guidelines for PCP development. This new technical approach recognizes the fact that pollution control is no longer synonymous with sewage treatment. Pollution control must necessarily deal with multiple pollution sources, contend with multiple water-use interests and involve multiple professional disciplines.

The product of a study undertaken with a MOE grant should be a PCP which satisfies the following requirements: comprehensive,

coordinated, incorporating best solutions and implementable.

Details of PCP study grants can be obtained from any MOE district office or the Water Resources Branch. This chapter will highlight the intent and the expected results of a PCP as envisioned in the general terms of reference.

3.2 THE COMPREHENSIVE NATURE OF A PCP

"Comprehensive" has several dimensions: (1) the study area should cover the entire jurisdictional area of the municipality wherever practicable, (2) all major pollution problems and major pollution sources should be investigated, and (3) all major water-use interests should be accommodated in the recommended solutions.

Ideally, the study area should cover the entire natural watershed of the receiving water. This was the approach taken by several watershed studies carried out in the seventies and early eighties. The disadvantages of the watershed approach are the tremendous study resources required; the extraordinarily long study period; and the diversity of the participating parties which complicates the successful implementation of the watershed plan. The best practical alternative is concentrating the study within the municipal jurisdictional area. This is the PCP approach and is a practical choice of priority. After all, experiences from previous watershed studies have shown that all major pollution remedial measures fell under municipal jurisdictions.

A PCP study should not be restricted to such popular priorities as basement flooding or pumping station overloading. Solving a problem in isolation may create a new problem. For example, if the overloading of a pumping station is solved alone by increasing the pumping capacity, the downstream sewage treatment plant may consequently be overloaded.

A PCP study should investigate pollution from sanitary sewage facilities, storm sewer discharges and combined sewer overflow. Pollution input from upstream sources should also be determined at the upstream boundaries of the study area. All major outfalls should also be investigated. This comprehensive investigation is necessary in order that pollution sources may be prioritized for control. It is not advisable, however, to investigate every outfall or other minor sources, as investigation work is very resource demanding. The benefit and usefulness of investigating minor

sources is low. Minor pollution sources should best be dealt with as local problems by abatement actions.

3.3 CO-ORDINATING A PCP

The need for coordination of all investigations and proposed solutions cannot be over-emphasized. The PCP study approach is designed to get rid of ad-hoc and piecemeal solutions. A few illustrations may be in order. Control of sanitary sewage pollution should not be considered exclusively of control of stormwater pollution. Mitigation of basement flooding in a combined sewer area should be considered in conjunction with combined sewer overflow control. The pursuit of pollution control at source cannot ignore assessment of receiving water impacts where the need for an assessment is well justified.

Coordination is also needed among various professional disciplines. Engineers, scientists, environmental planners, economists and financial analysts have various roles to play in a PCP study. They must learn to understand the positions of one another and consult with one another in order to develop a PCP with a good balance of conflicting interests.

3.4 PCP ANALYSIS TECHNIQUES

The best applicable analysis techniques should be used in the development of a PCP. Analysis results have great influence on the selection of pollution control measures. But what is best? For the analysis of a sanitary sewage system, the best technique may be recognized quite readily. It is not so in the case of analysis of stormwater pollution, or combined sewer overflow, or receiving water impacts. These three types of physical processes are complex and involve many parameters. The processes are hardly amenable to complete representation by scientific expressions. Some parameters such as rainfall are widely variable. Some parameters such as the physiography of the catchments and the planning of urban developments are non-uniform. No single criterion can suffice for selecting the best technique. The answer may be the technique that best satisfies the following criteria.

1. The technique should be capable of simulating the physical process as closely as practically possible. For example, a technique for combined sewer overflow

analysis should have the capability of computing sewer hydraulics.

2. The computational procedures used in the technique should be scientifically sound.

3. All major parameters of the system to be analyzed should be represented in the computational procedure. The amount of data required, however, should not be weighed down by parameters of secondary importance.

4. The uncertainty of the analysis results can be estimated.

5. The cost of using the technique is reasonable.

Needless to say, the best technique can still produce bad results unless the technique is applied judiciously by an experienced professional.

The technique for the analysis of a pollution control facility, e.g. a stormwater pollution treatment pond, usually contains an assumed efficiency of the facility. Caution is needed in the use of the technique and in the interpretation of analysis results. The true performances of many stormwater pollution control technologies have yet to be verified in full-scale applications.

3.5 PCP IMPLEMENTATION

A PCP should be implementable. To satisfy this requirement, a PCP must contain both investigation results and recommendations for pollution remedial measures. There must be sufficient detail on the recommended remedial measures. The required information normally includes the key features of each proposed remedial measure, its location, required capacity, estimated performance, estimated pollution control effects, costs, feasibility, impact evaluation, financing, implementation timing, a proposal for post-commissioning evaluation, possible alternative solutions, and a comparison of the recommended solution with the alternatives.

The information should be presented in such a way that it can be used for making a decision on the implementation of the PCP. The climax of a PCP study is the event of receiving approval for implementation of the PCP.

3.6 CONCLUSION

Summing up, the new technical approach is comprehensive, coordinated, implementable and based on best analysis techniques and solutions. By possessing these attributes, a PCP is the key to successful pollution remedy.

But benefits of this key methodology will not materialize unless MOE, the municipality and the consulting engineers participate in formulating a PCP and getting it approved for implementation!

CHAPTER 4

Pollutants - How to Look at Them in their Proper Perspective

Isobel W. Heathcote

4.1 DEFINING THE PROBLEM

4.1.1 Introduction

One of the first questions to be asked in the preparation of a Pollution Control Plan is "What is the problem?"

This seems an obvious, even a trivial, question, but in fact the answer to it will form the basis for a program of pollutant measurement and remedial action formulation, and indeed for the entire pollution control plan. Different areas have different problems, and one jurisdiction may assign a different importance to a particular problem than an adjacent jurisdiction might. In general, a "problem" can be defined as an impairment of a desired water use.

4.1.2 Beneficial Uses of Water

Beneficial water uses may be classified as follows:

1. drinking water,
2. swimming and bathing,
3. aquatic life habitat,
4. agriculture (esp. livestock watering and irrigation),
5. industry (esp. process and cooling waters), and
6. other uses such as fire protection, navigation, and power generation, which tend to be less sensitive

to water quality.

Each of these uses requires a particular quality of water, but the quality required for drinking water, for instance, is not necessarily the same as that required for swimming or for agriculture. The water manager's first step in developing a pollution control plan is to identify which, if any, of these uses is impaired in the jurisdiction of interest.

After identifying the particular use impairment(s), the manager's next task is to define the desired level of improvement for each. In this, it is not sufficient to state, for instance, that beaches should be "swimmable", because "swimmability" is defined in different ways by different people. The manager, in consultation with municipal planning bodies, should identify precisely *how* and *when* improvement will be measured. In particular, it will be necessary to select parameters that will reflect movement towards the desired goal, and to define target concentrations for each.

In some instances, particularly in cases of bacterial contamination, it may be necessary to vary targets depending on other conditions such as rainfall. It may not, for example, be practical for a municipality to improve beach conditions to a point where swimming is safe in wet and dry weather (after all, few people would choose to swim during a rain storm). It might be argued that the additional treatment and/or storage costs associated with wet- *and* dry-weather control of beach contamination are unjustifiable in view of the low probable use of beaches in wet weather. Instead, the municipality may decide that it is enough to have beaches swimmable within 48 hours of a rainfall.

In general, it is not necessary to measure every parameter of interest for a particular water use. There are often hundreds of parameters that *could* be included in a monitoring program; the manager's task is to identify key parameters upon which policy decisions may be based, and to measure them well enough to be able to predict changes in the system following proposed remedial measures.

Table 4.1 summarizes the major classes of pollutants of concern for each major water use. Selection of specific parameters for a particular sample program will depend on prevailing local conditions, municipal priorities, and the water quality manager's knowledge of the

Table 4.1 Major Water Uses and Water Quality Parameters of Concern

WATER USE	WATER QUALITY PARAMETERS OF PRIMARY CONCERN
Drinking Water Supply	Primarily related to potential for human health hazard; usually includes one or more bacterial parameters, radionuclides, toxic organic and inorganic chemicals; also considerations of taste, odour, colour, hardness, turbidity, and likelihood of forming encrustations or corroding water supply equipment. *Symptoms of Use Impairment:* various, see above
Swimming and Bathing	Primarily related to potential for human health hazard; also aesthetics (debris, oil, scum colour, taste, turbidity) and pH. *Symptoms of Use Impairment:* usually bacterial contamination or aesthetic impairment.
Aquatic Life Habitat	Various; includes pH, temperature, acutely toxic pollutants such as chlorine and ammonia; dissolved oxygen; sulphides; phosphorus (because of potential to encourage eutrophication); radionuclides; toxic organic and inorganic contaminants. *Symptoms of Use Impairment:* Various and dependent upon indigenous biota; may be acute or chronic; can include eutrophication (algae blooms, depressed dissolved oxygen).
Agriculture	Similar to drinking water; some livestock may be tolerant of high suspended solids or bacterial levels; special conditions may be required to make water acceptable to livestock or to provide special rearing conditions; irrigation water quality depends on crop but important consideration include chlorides, bicarbonates, temperature, pH, radionuclides, microbiological parameters, and toxic chemicals. *Symptoms of Impaired Use:* various, dependent on crop or stock being raised, special conditions desired or previously in place; may be acute or chronic (death or "failure to thrive").
Industry	Process or cooling waters; if the former, may depend on product and process; can include temperature, pH, turbidity; colour; hardness. *Symptoms of Impaired Use:* equipment fouling, process upsets.

nature and volume of local pollutant discharges. Where the manager has inadequate data on local facilities and dischargers, it is wise to conduct preliminary sampling of effluents for a broad range of parameters, to determine which contaminants are of most concern and how they vary in space and time. Provincial water quality objectives (PWQO) have been developed for a number of contaminants and are described in the Ministry of the Environment's "Blue Book" (MOE, 1984); however, guidelines are not available for many industrial organic chemicals and a number of other contaminants. In these cases, decision makers may need to decide themselves on preferred target values based on available toxicity information. Additional guidance on these issues is provided by Heathcote (1987).

Finally, it is important to remember that for a number of contaminants, the PWQO are linked to other parameters such as temperature and pH. For example, the un-ionized fraction of total ammonia is most of concern with respect to acute toxicity. The percentage of un-ionized ammonia increases with increasing temperature and pH; a measurement of total ammonia alone would therefore be insufficient to assess potential environmental impact. Similarly, the PWQO for lead increases with increasing alkalinity, so to evaluate lead toxicity correctly it is also important to know ambient alkalinity. Another example is the PWQO for dissolved oxygen, which depends on water temperature, because warmer waters are able to hold less oxygen. Finally, for a number of organic contaminants, the PWQO is set as a sum of the contaminant and its breakdown products or isomers. Examples of this are PWQO for "DDT and metabolites", for "aldrin plus dieldrin", and for "heptachlor plus heptachlor epoxide".

4.2 USE IMPAIRMENT AND POLLUTANT CLASSIFICATION

Concerns about water quality usually arise from impairment of beneficial water uses, such as fishing, swimming, and aesthetics. Public awareness of use impairment is often related to one of the following problems:

1. public health issues, such as increased frequency

of illness among people using bathing beaches;
2. unattractive or fetid waters, sometimes caused by eutrophication and the resulting excess plant growth and decay;
3. fish kills or otherwise visible evidence of impacts on aquatic biota, sometimes caused by depressed dissolved oxygen (which can be caused by eutrophication) or by toxic pollutants; or
4. other problems such as high turbidity, excess heat, or radionuclide contamination, which may be immediately visible or may be expressed in fish kills or high tumour rates.

For convenience, pollutants are often grouped in several major classes depending on their chemical nature, their toxicological action, and other factors. A typical classification of pollutants is given in Table 4.1. An observed use impairment, for instance the loss of a self-sustaining fishery, could be due to the combined action of several types of pollutant or to a single primary influence.

Use impairment is not always easy to detect. It may take many forms, sometimes immediately visible (like a fish kill) and sometimes more subtle and insidious (like an increase in the frequency of tumours in a fish population). In some cases, a single pollutant can have acute (short-term, dramatic) effects or chronic (longer-term, more subtle) effects, depending on its concentration and the sensitivity of indigenous biota.

As an example, acute (often fatal) mercury poisoning in humans is characterized by nausea, vomiting, diarrhoea, shock, circulatory collapse and, ultimately, death. Acute mercury poisoning is usually brought on by a high dose consumed over a short time. Partly because of the dramatic and obvious cause-and-effect relationship, there is usually no question that a toxic effect is present, and what has caused it.

By contrast, chronic (sub-lethal) mercury poisoning in humans, which follows long-term exposure to lower concentrations, is characterized by kidney disease, personality changes, drowsiness, confusion, tremor, pain, fever, muscle weakness, and other subtle changes. Under these circumstances, it is far more likely that the effects would be dismissed as psychosomatic or attributed to causes

other than mercury. When several toxins are at work simultaneously, the cause-effect relationship can be even more difficult to discern.

Even the pollutants themselves can be difficult to track in the aquatic system. Some are considered to be "conservative" (that is, experiencing no growth or decay in the natural environment), so "what goes into the system must come out". Others are considered "non-conservative" (increasing or decreasing in mass as time passes). It can be more difficult to assess and rank sources of non-conservative pollutants, and thus to know when and where to measure them, because they can be created or destroyed in the system. Examples of conservative parameters are total phosphorus, chloride, and conductivity. Examples of non-conservative parameters are bacteria (which may either grow or die off, depending on ambient conditions), ammonia (which is converted to nitrite and then to nitrate) and volatile substances such as chlorine.

Finally, some pollutants "bio-accumulate" or "bio-magnify". That is, some contaminants are not easily broken down and excreted from biological tissue. In consequence, a "body burden" of the contaminant builds up in the body of an organism. In a planktonic plant, the concentration of the pollutant in the organism's body may be at equilibrium with the concentration in ambient waters.

When higher level animals in the food chain consume the organism, they also consume its pollutant burden. The problem is that each successively higher level in the food chain must consume larger quantities of prey organisms to compensate for energy losses and metabolic demands. (Some authors estimate that only about 10% of the energy present in a prey organism is actually available to the organism consuming it, primarily because of energy lost as heat during energy transformation processes.) Higher level consumers therefore receive large doses of the contaminant, which they in turn will accumulate in their body tissues. This process continues up the food chain, with organisms at the top of the food chain carrying the largest "body burden" of pollutant - hence the terms "bio-accumulation" or "bio-magnification".

As humans, we tend to set ourselves apart from this process. However, we are in fact top carnivores in the food chain and very much at risk (how great a risk is a matter for debate) from bioaccumulating toxins.

4.3 METHODS OF EXPRESSION OF POLLUTANT STRENGTH

4.3.1 Concentration

Typically, the strength of a pollutant is measured in concentration - the mass of pollutant (expressed in grams, milligrams, micrograms, or similar measures) per unit of volume (usually a litre).

There are exceptions. Bacterial parameters are measured in various ways but most frequently as the estimated number of organisms (e.g. "Most Probable Number") present in a specified volume of water (in this case usually 100 mL). pH is measured in "standard units" which are in fact the logarithm of the reciprocal of hydrogen ion concentration in gram atom per litre in the sample. Turbidity is measured in special units (e.g. "Formazin Turbidity Units") which are indicative of light transmission potential. Conductivity is measured in micromhos per centimetre; micromhos are the inverse of ohms, a measure of resistivity.

However, pollutants such as phosphorus and nitrogen compounds, heavy metals, trace organic contaminants, and most others are measured in milligrams per litre in water, and in milligrams or micrograms per gram (or kilogram) in sediment and biological tissues.

But pollutant strength is not the only consideration in assessing environmental impact potential. Concentration gives only a snapshot in time, and a single measurement of concentration may or may not be representative of overall environmental conditions. It is also important to understand the likely exposure period for organisms (including humans) which may be at risk from the contamination.

For example, a company that discharges 1 µg/L of a pollutant, but discharges hundreds of thousands of litres of effluent, round the clock, 365 days a year, may sometimes be considered a more serious problem than a company that discharges 1,000 µg/L = 1 mg/L in 1,000 L of effluent but discharges only two days a year. For this reason, the concept of "loading" is very important in pollution control.

4.3.2 Loading

"Loading" refers to the total mass of pollutant discharged, and is calculated as the product of concentration and discharge volume. "Loading rate" refers to the total mass discharged per unit time. Table 4.2 illustrates these concepts with the examples from Section 4.3.1 above. Company 1, the continuous, low-concentration discharger, produces an annual total load of 182.5 grams, over 90 times more pollutant mass than Company 2, the short-duration, high concentration discharger.

Table 4.2 Examples of Pollutant Concentration and Loading.

Company	Concentration	Discharge Flow	Annual Total Load
1	1 mg/L	500,000 L/d (365 days)	182.5 grams
2	1,000 mg/L	1,000 L/d (2 days only)	2.0 grams

Yet Company 1 is not necessarily "better" or "worse" than Company 2; each has its own reason for concern. In terms of total impact on the environment, for instance in the case of a persistent and bioaccumulative substance such as mercury or DDT, the first polluter may be of the greatest concern, even though its effluent concentration is routinely much lower. Company 1 may also be of greater concern where target total loads have been set for a receiving environment or for a particular discharger.

However, Company 2 may be a more serious problem if the pollutant it is discharging is acutely toxic to aquatic biota. In that case, the higher the concentration, the more dramatic the impact on the aquatic community.

The point is that, depending on the nature of the pollutant, its toxicity, its persistence, and other factors, it may be important to understand not only the concentration of the pollutant in the effluent,

but also the rate and timing of effluent discharge (and therefore the loading rate for the pollutant) and the total pollutant load discharged over a unit of time. Table 4.3 shows the differences between the example Companies 1 and 2 with respect to each of these considerations. In some cases, Company 1 is the worse offender; in others Company 2 is worse.

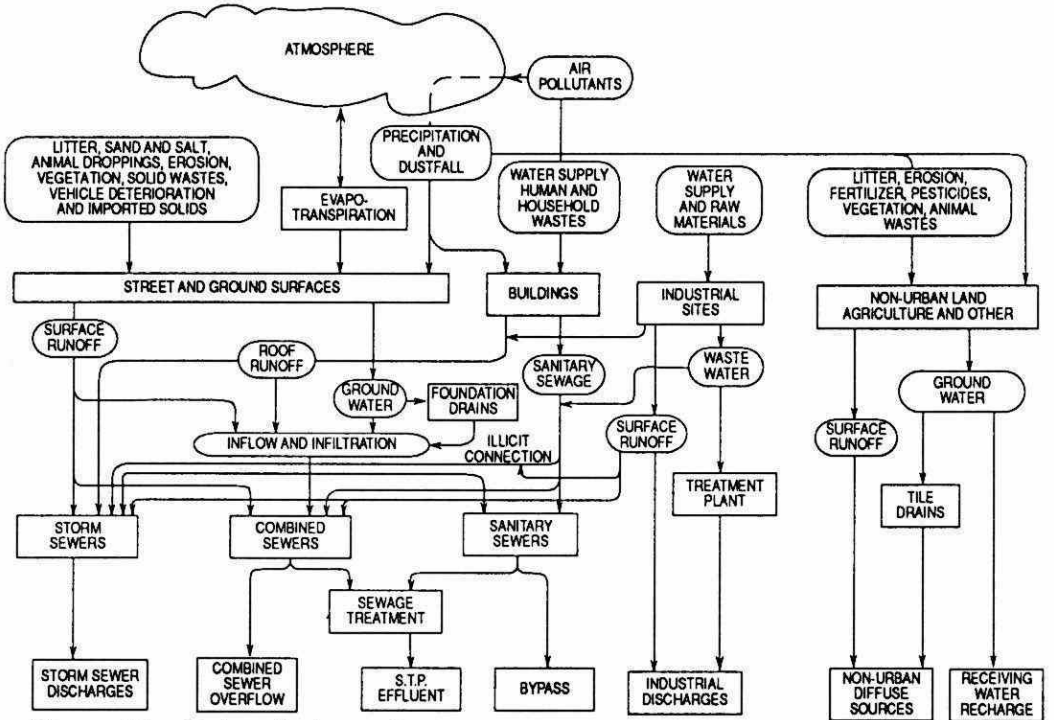
Table 4.3 Concentration, Loading Rate and Total Load for Two Discharge Scenarios.

Measurement	Company 1	Company 2
Concentration (e.g. mg/L)	Low	High
Instantaneous Loading Rate (e.g. kg/March 23)	Low	Low to High
Average Loading Rate (e.g. average kg/day)	Low	Low
Total Annual Load (e.g. kg)	High	Low

4.4 SOURCES OF AQUATIC POLLUTANTS

The sources of pollutants in a pollution control planning area are diverse; Figure 4.1 illustrates some of them. The Urban Drainage Policy Implementation Committee Sub-Committee No. 2 (1987) using data from several sources estimate that combined sewers can contribute more than 10 times the total phosphorus yielded by rural non-point sources, and more than 6 times the phosphorus contributed by urban commercial, industrial and residential areas. Table 4.4 shows some typical concentrations and estimated loadings for major pollutant sources.

Figure 4.1 Sources and movements of pollutants in a PCP planning area



Source: Urban Drainage Implementation Committee Sub-Committee No.2 (1987)

For toxic inorganic and organic contaminants, a significant source can be indirect industrial discharges to municipal sewer systems. Because municipal wastewater treatment plants are not equipped to treat complex industrial effluents, many toxic chemicals persist through the treatment process and are discharged into receiving waters in treated effluents. Ontario's MISA program has begun to investigate these indirect dischargers and possible solutions for their control. These might include a requirement to pretreat industrial effluents before discharge to sewers, or (preferably) voluntary control of toxic chemical use at source by product/process modification and improved "house-keeping" practices.

4.5 ASSESSING VARIABILITY IN SOURCES AND RECEIVERS

Regardless of the number or type of pollutants selected for a sampling program, it will be important to understand how the concentration of those pollutants varies in space and time. This is true both for effluents (which, depending on the process and product, can be highly variable in time) and for the receiving environment, which can vary significantly in both time and space.

The main problem with any sampling program is to guess what the true or usual value is from a limited number of "snapshot" assessments. The sampler's task is to design a cost-effective sampling program that uses the least number of parameters, sampled the least number of times and places, that will still provide useful data. The catch is that the fewer the "snapshots", the poorer one's ability to guess accurately. Good experimental design is therefore a problem of trading off high costs against usable data.

Table 4.4 Characteristics of Potential Pollutant Sources

(a) CONCENTRATIONS

SOURCE	BOD (mg/L)	SS (mg/L)	TOTAL N (mg/L)	TOTAL P (mg/L)	TOTAL COLI-FORMS (#/100 ML)	FECAL COLI-FORMS (#/100 ML)
Raw Sewage[a]	165	225	30	6.5	10^8	10^7
Treatment By-Pass[a]	119	280	25(TKN)	4.5	-	
-Primary	50	50	22	1.0	10^7	10^6
-Secondary	17	23	18	1.0	10^4	10^3
Combined Sewer[a] Overflow	41	190	8.3	1.4	10^7	10^6
Urban Surface[a] Runoff	14	170	3.5	0.35	2×10^4	5×10^3
Non-Urban Runoff	(See Areal Loading Data)					
Industrial	(Variable Dependent on Industrial Processes and Manufactured Products)					

(Source: Urban Drainage Implementation Committee Sub-Committee No.2 (1987))

[a] (COA, 1980A)

Table 4.4 (cont)
(b) AREAL LOADINGS (kg/ha/year)

LAND USE	BOD_5	SS	TKN	NO_3.N	TOTAL P
Urban - Commercial[b]	43	825	11.0	-	0.18
Industrial[b]	42	1082	14.0	-	0.92
Residential[b]	33	619	5.0	-	0.42
Rural General[c]	18	569	11.7	7.70	0.90
Wooded/Idle/Perennial Cover[c]	5	40.7	5.15	3.30	0.08
Combined Sewer Overflows	240	645	60	-	9.7

[b] Waller and Novak (1981) [c] Wanielista (1978)

4.5.1 Factors Affecting Pollutant Variability

Pollutant behaviour in a receiving environment depends on a variety of factors, including physical factors (e.g. convection, diffusion, sedimentation, light attenuation); chemical factors (e.g. hydrolysis, ionization, reaction kinetics); and biological factors (e.g. growth and death of organisms, uptake by plants, photosynthesis and respiration). In addition, it is important to know whether a parameter is conservative or non-conservative, and whether it tends to bioaccumulate.

Pollutants have different inherent variabilities, but each pollutant's variability will also differ depending on the characteristics of the receiving environment. It is therefore difficult to generalize about the "correct" monitoring frequency for a particular contaminant. The "right" answer will depend on the nature of the ambient system and on the objectives of the sampling program. For instance, a program aimed at determining average annual concentrations of copper in

(typically quite stable) offshore Lake Ontario might require only 12 to 15 monthly samples to obtain an estimate with reasonable statistical confidence. However, a program designed to track (rapid and variable) declines in bacterial concentration at bathing beaches following rainstorms would likely require frequent, perhaps hourly, sampling over several days. It would thus be wise to monitor the declines following several rainstorms of different intensities, and to sample different indicator or pathogen bacteria species.

A sampling program must be adapted to the inherent variabilities of the parameters it measures, and to the characteristics of the receiving system. If the sampler is able to estimate the mean and standard deviation of the data, it is possible to estimate the number of samples required to achieve a particular level of statistical confidence. Techniques for this are beyond the scope of this report, but are available in many standard texts on statistics.

A 1984 MOE data set for the Grand River at Dunnville revealed the variabilities for typical water quality constituents given in Table 4.5 below.

Table 4.5 Variability in water quantity constituents

Parameter	Range	Mean	Standard Deviation
Temperature	0-27.0°	10.6	NA
Dissolved Oxygen	6.9-13.2 mg/l	10.5	1.82
Total Phosphorus	0.047-0.89 mg/L	0.134	0.105
Filtered Ammonia	002-0.94 mg/L	0.196	0.196
Suspended Soils	1.508-836.00 mg/L	65.917	102.765
Zinc	0.005-0.017 mg/L	0.010	0.003
PCB (Total)	6-20 ng/L	14	7

Source: MOE 1984

These results show that for some parameters (e.g. zinc), variability was very low. Other parameters show high variability (e.g. suspended solids), presumably because of variability in their sources or in the behaviour of the receiving system. A single sample of zinc *in this particular system* might give you a reasonable guess at a typical concentration for that parameter. However, a single sample of suspended solids might give you a very high value, or a very low value, or possibly a value somewhere in the middle. It certainly would not give you an accurate picture of the overall behaviour and typical range of concentrations for that parameter. Even knowledge of the average value may not be enough; with some pollutants environmental impact may be most closely linked to peak concentrations, so it is also important to know the probable *range* of values.

4.5.2 The Special Case of Bacteria

Bacteria are a particular problem in terms of high variability. Normal, relatively unpolluted surface waters have fecal coliform bacteria densities of less than 100 org/100 mL. Concentrations in pollution sources (CSO, urban runoff, etc.) can be several orders of magnitude higher - in the thousands or millions. (Simply because bacterial values vary so greatly, average bacterial concentrations are usually expressed as a geometric average, that is, the anti-logarithm of the average of the logarithms of the values.)

These concentrations are reduced in surface waters by a combination of dilution and die-off. Die-off can be rapid or slow depending on factors such as incident light, temperature, the presence or absence of particular chemical constituents, and other factors.

In situations requiring the monitoring of bacterial densities, it is usual to take a number of samples. The MOE's "Blue Book" (1984) recommends that at least ten samples per month be collected per sampling location, but states also that increased frequency would be required when the waters are used for recreational purposes or when the water is subjected to contamination or discharge. The Blue Book does not presently state a required or recommended timing of sampling - i.e. one a day for ten days? ten a day for one day? one every three days for a month? Obviously, each strategy would yield a

different answer. The problem again is to understand in a general way how the system is likely to vary, and to adapt the sampling strategy to that system behaviour.

For instance, if the system receives only dry weather trickling of bacterial loads (small volume, high concentration, consistent flow and therefore reasonably low variability), it may be possible to sample once a day and still achieve a reasonable estimate of the true "average" value.

On the other hand, if the system is affected by wet weather discharges such as CSOs, sewage treatment plant bypass or urban stormwater, it may experience concentrations that rise several orders of magnitude over a period of an hour or two, and then take several or many hours to subside. In this case, a number of samples taken close together - perhaps as often as every ten or fifteen minutes - would be required to capture the variability in the system. (It is important to note that composite samples - composed of aliquots mixed together - are of little use in defining system variability because they provide only the average value of the mixed samples; they give no measure of the range of concentrations present in the individual aliquots.) Again, a knowledge of how the system works should provide guidance in deciding on an appropriate strategy.

A further complication of sampling bacterial parameters is choosing which group(s) or species will best predict the presence of a human health hazard. Until recently, it was usual to use easily-measured groups of bacteria, such as the fecal coliform and fecal streptococcus groups, as suggestive of the presence of pathogenic organisms. Now other clearly pathogenic, but less easily measured species such as *Escherischia coli* or *Pseudomonas aeruginosa* are becoming more commonly analyzed. The difficulty of using the fecal coliform group is that many such indicator organisms do not cause human illness, and are still a matter of controversy (such as *Klebsiella* sp.). The mere presence of fecal coliform bacteria, therefore, does not guarantee that a human health hazard will be present. By contrast, the presence of a known human pathogen, in sufficient quantities, is indeed reason for concern. (Viruses are of course also of concern, but laboratory protocols for these parameters are as yet few and unreliable.)

Because of this, organizations such as the International Joint Commission (IJC) and the Ontario Ministries of Health and the Environment are examining new criteria for bacterial contamination. The preferred approach seems to be a multiple-test system combining indicator species with specific pathogens. Nevertheless, current MOE water quality objectives for bacteria (MOE 1984) continue to be based only on fecal coliforms and total coliforms.

4.5.3 Variability in Space

It is important to consider not only the variability of a pollutant in time, but also its variability in space. Some systems, for instance small, fast flowing streams, may experience turbulence to such an extent that their waters are in fact well-mixed and more or less uniform. In other systems, including larger rivers and lakes, pollutants tend to be distributed non-uniformly. This is a matter for concern where concentrations or loads in some areas are unacceptable, while conditions in other areas are favourable for recreation and other uses. It may be necessary for the planner to define the zone(s) of deteriorated and undeteriorated water quality and perhaps to develop separate plans for each. It is therefore particularly important that the planner not make assumptions about system behaviour, and parameter distribution in the system, without field evidence to confirm those assumptions.

Depending on the complexity of the system, many samples may be necessary to detect or delineate the concentration gradients present in a water column. In a lake, for example, thermal stratification of lake waters in summer and winter can have a dramatic effect on the distribution of pollutants through the water column. Similarly, the presence of a diffuser outfall can create a pattern of high concentrations close to the diffuser, diminishing to background concentrations at distance.

4.5.4 Using Available Data

One useful method of extending a data base is a literature review to identify the nature and extent of existing data. Potential sources of this information are federal, provincial and municipal government publications and unpublished but potentially available

raw data, conservation authority studies, consultant reports (usually requiring the consent of the client), and articles in scientific journals. University libraries can be an excellent starting place for such a literature search. Their collections are often large enough to encompass most relevant literature, and computer-assisted literature search services, based on key words, may be available to speed the task.

4.6 THE "BLUE BOOK": EVALUATING DATA

4.6.1 Evaluating Present Conditions and Future Improvements

As part of the problem identification exercise described in Section 4.1, it will be necessary to evaluate available data from all sources: how serious is the problem? how much needs to be done to make the situation acceptable to stakeholders?

An obvious first step in data analysis is to compare data on existing conditions with MOE objectives for ambient water quality and, depending on the situation, for drinking water, livestock watering and irrigation uses. At present, Ontario has no laws governing the quality of any water source for any use. However, as discussed above, guidelines and objectives exist for a number of pollutants. Most of these are so-called conventional pollutants such as phosphorus, nitrogen and suspended solids. Objectives for the many toxic organic and inorganic chemicals are much fewer in number. Details of these objectives can be found in the Ministry's "Blue Book" (MOE, 1984).

It is to be hoped that the process of problem identification and goal setting described in Section 4.1 would lead to the determination of a specific desired quality. For example, if a problem of bacterial contamination of beaches has been identified, a target desired quality could be expressed as something like "within 24 hours of a major rainfall, at 1 m depth, 30 m from shore, quality should be fecal coliforms less than 100 organisms per 100 mL, and *Pseudomonas aeruginosa* less than 2 organisms per 100 mL. This type of clear criterion makes it very simple to assess the results of modelling or other predictive studies that estimate conditions under future remedial scenarios. Here again, the objectives governing each

desired use are contained in the Ministry's "Blue Book". However, for planning purposes a jurisdiction may choose a more or less stringent level of control, depending on the nature of the problem, the nature of the receiving system, and the needs and concerns of local residents.

4.6.2 Receiving Water Objectives vs End-of-Pipe. Standards

It must be noted that the water quality objectives described in the "Blue Book" are entirely receiving-water based. That is, they outline desirable quality for natural waters to be used for various purposes. They do not (nor could they in any simple fashion) relate those receiving water levels to the quality of local pollutant sources. So while the "Blue Book" objectives are clear, easily interpreted, and easily applied, they are geared to general water management and not to enforcement of specific controls. The decentralized organization of the MOE further complicates this in that application of the "Blue Book" policies can differ from region to region, sometimes dramatically.

The emphasis on receiving environment quality that is apparent in the "Blue Book" is typical of Ontario environmental policy over the past twenty years. In the United States, it has been more common to manage water quality by regulating discharges at the "end of the pipe". Such an approach is obviously much easier to implement and to enforce, because "ownership" of pollution is usually clear-cut. The arguments often cited against end-of-pipe regulation are that it fails to measure (or control) actual impact on the receiving environment, and that it may not encourage the development of innovative pollution control technologies.

The Ministry of the Environment MISA program is directed at getting the best of both these worlds (MOE 1986). Its goal is to reduce toxic chemical discharges to receiving waters in Ontario by regulating direct and indirect (i.e. via municipal sewage treatment plant) industrial dischargers on a sector-by-sector basis. For the first time, Ontario will develop regulations that require industries to reduce their discharges to "Best Available Technology" (BAT) levels - consistent with the approach taken by the U.S. Environmental Protection Agency. The regulations will be in two parts. The first phase will produce monitoring regulations that define what an industry

must measure in its effluents over a one-year period. The second part will define and enforce BAT controls on those discharges, with those controls specific to each industrial or municipal sector.

Nevertheless, the Ministry has recognized the need for stricter controls in areas where the receiving environment is particularly sensitive. In these cases, MISA will provide for site-specific controls to protect the receiver.

A valuable adjunct to the MISA program is the development of a data base for the Effluent Monitoring Priority Pollutant List (EMPPL) of toxic chemicals. At present, little is known about the discharges of particular industries. The data collected through the MISA monitoring regulation, and the screening of compounds for the EMPPL list, will provide essential data for the development of effective toxics controls.

4.7 FUTURE DIRECTIONS

The Ministry of the Environment's MISA program heralds a new era of pollution control regulation in Ontario. As mentioned in Section 4.6 above, the data collected through EMPPL and MISA screening programs will provide the Ministry with an increasingly large body of information about the toxicity of pollutants, their presence in industrial and municipal effluents, and their loadings to receiving waters in the Province.

These data will help water managers in determining what we should be measuring in receiving waters, and where, and to a certain extent, how.

Along with the growth of MISA and EMPPL will come, by necessity, the development of better laboratory protocols for detecting and quantifying low-level chemicals in water. Better detection capability will mean more accurate knowledge of effluents and an improved ability to define desirable levels of control - and ultimately, a cleaner environment.

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CHAPTER 5

Formulation, Evaluation and Screening of Pollution Control Plans*

Casey Kennedy and George Zukovs

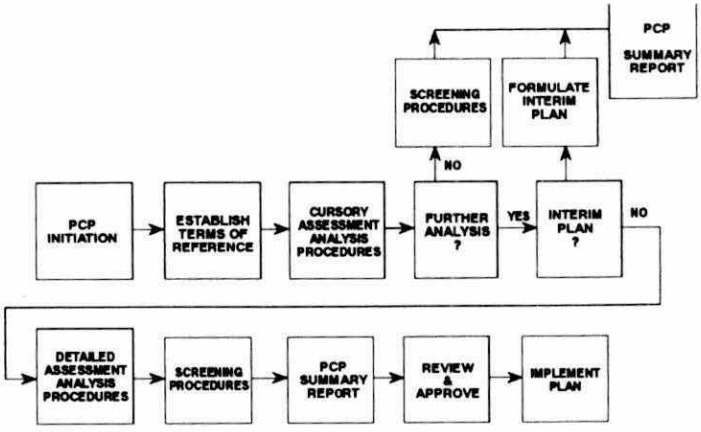
* (Based on the MOE report "Technical Guidelines For Preparing A Pollution Control Plan", 1987)

5.1 INTRODUCTION

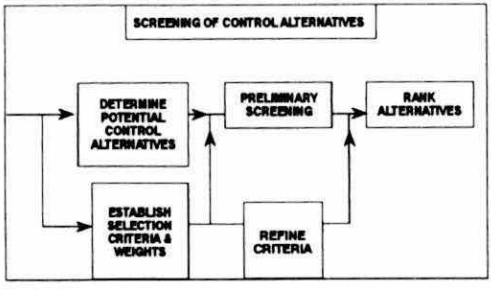
The Pollution Control Plan process is intended to provide the framework necessary to formulate management decisions regarding water pollution control expenditures. The PCP structures the necessary technical, economic and public opinion data for the benefit of the decision makers. The public participation component of the PCP gauges the public perception of water management problems and enables the concerns of the public to be incorporated into action plans. The objective of the PCP is to comprehensively document the future course of pollution control in a community. Once this has been accomplished both the municipality and the province will be better able to estimate funding requirements.

Figure 5.1 outlines the PCP process from initiation to the final report. Although the process is depicted as linear, it is actually repetitive with any number of the steps repeated until the plan perceived as "best" is identified. The objective of this process is to list alternative pollution control plans and identify the one with the greatest merit. The alternative that is selected as the "best" will be, in most cases, the least-cost plan that meets the Provincial Water Quality Objectives. In order to determine the "best" plan, public participation has to be incorporated into the process. The public should not only be made aware of the study, but should also be asked to participate in it from its initiation.

Figure 5.1 Steps in Pollution Control Plan Preparation



NOTE: Screening procedures are actually a component of cursory or detailed assessment procedures, but are shown here separately for purposes of illustration.



Source: "Technical Guidelines for Preparing a Pollution Control Plan," MOE (1987).

The formulation of a PCP is dependent on several factors:

1. whether the plan involves a single party or is a cooperative effort,
2. the importance and severity of water quality problems,
3. the availability of water quality and pollutant source data, and
4. the applicability and relevance of previous planning studies.

Once a PCP has been initiated the terms of reference are prepared. The terms of reference establish the technical and administrative basis of the PCP. Once the terms of reference are set the study can commence.

The cursory and detailed assessments provide the criteria for the evaluation of the PCP. The cursory assessment can be carried out once the study is underway. This is the initial study phase in the preparation of the PCP (in some cases it is the only study phase). The cursory assessment identifies and characterizes the pollutant sources, water uses, and where possible, management plans for the study area. The scope of the cursory assessment is dependent upon whether similar or complementary studies have been carried out in recent years within the study area. The cursory assessment should always utilize the simplest possible approach and rely, as much as possible, on existing data sources.

If the cursory assessment (or the terms of reference) indicates the need for more sophisticated modelling of pollutant sources, control measures or water quality impacts then a detailed assessment should be conducted. A detailed assessment involves the collection of additional data, the application of sophisticated models (pollutant source and receiving water) and further analysis of inflow/infiltration problems.

The screening criteria for a PCP should be developed as early in the process as possible. The terms of reference should outline specific water quality criteria (e.g. BOD, total phosphorus) as well as any other relevant criteria (such as the distribution of control costs among the parties involved in the PCP).

The final output from the PCP is a Summary Report which will include an implementation plan identifying the management actions required from each of the parties involved in the PCP.

The following discussion is intended to provide insight into the formulation, evaluation and screening of pollution control plans.

5.2 FORMULATION

Prior to plan formulation all possible pollution control measures have to be identified. Based upon the knowledge of the behaviour of pollutant sources and the receiving water that is gained

during the cursory and/or the detailed assessment stage, it should be possible to identify suitable potential control measures or abatement actions. The identification of the control measures is initially made on a source and pollutant specific basis.

In order to exemplify this process a hypothetical case will be studied. The schematic in Figure 5.2 depicts a beach area that is impacted by two separate communities, each with its own pollutant sources. Community `A' impacts the beach through stormwater runoff and intermittent dry weather sources, while community `B' has the same pollutant sources as well as wet weather bypass of sanitary sewage. Table 5.1 lists control alternatives for the three sources from both communities and for the stream itself. Since two of the sources are common to both communities it is not necessary to duplicate the control alternatives in this list. There is no rigorous method of identifying potential measures, therefore, reliance is placed upon the expertise and insight of the analyst to identify useful alternatives.

Another method of listing potential control measures is to include the pollutant species. Table 5.2 lists the potential control measures for a receiving water that is impacted by bacterial and heavy metal inputs from a combined sewer overflow (CSO) and bacterial inputs from intermittent dry weather sources (i.e. cross connections).

The next step in the process is to group the listed pollution control measures into a number of alternative plans. Table 5.3 depicts alternative pollution control plans based upon the control measures listed in Table 5.1. The alternative control plans are separated based on pollutant sources. Plan A deals with wet weather bypass controls whereas Plan B deals with the two pollutant sources that were common to both communities. During this phase of the plan a systematic effort is made to examine all feasible combinations of pollution control measures to solve the entire problem. More than one control measure for a given source may be used in various combinations to create new plans (eg. A-3 in Table 5.3).

Figure 5.2 Schematic of a Hypothetical Example

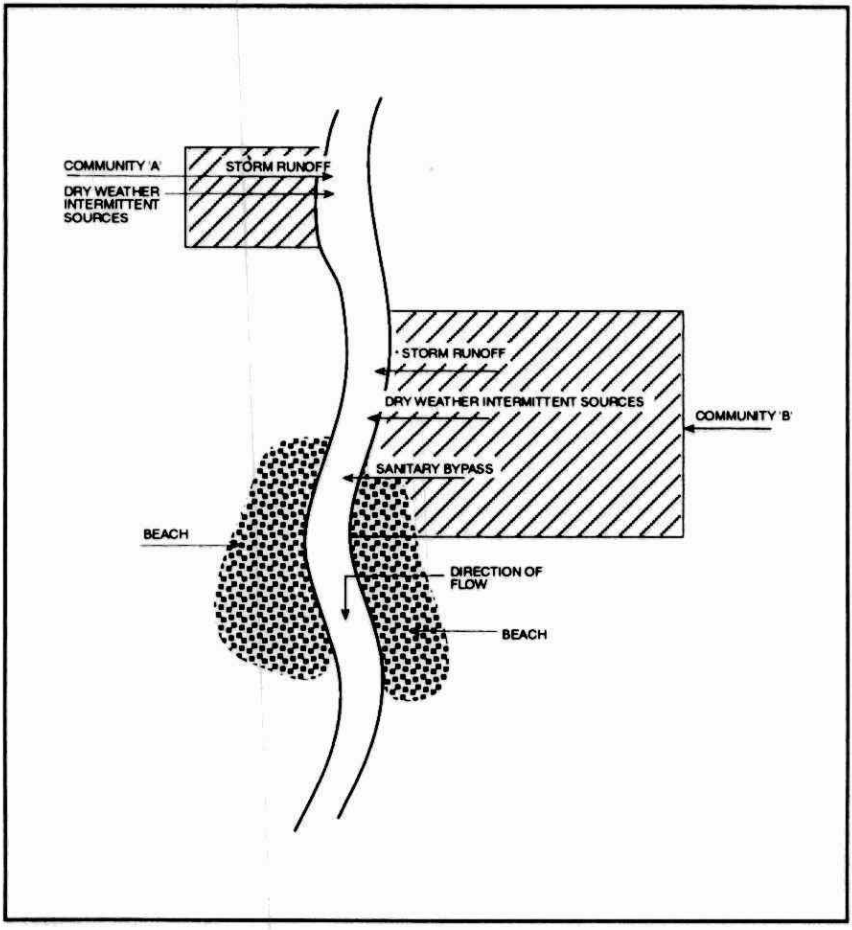


Table 5.1 Control Alternatives for Hypothetical Example

DRY WEATHER INTERMITTENT SOURCES	WET WEATHER BYPASS	STORM RUNOFF	IN-STREAM
1) Disconnection of cross-connections.	1) Storage and high rate disinfection at WPCP.	1) Street sweeping	1) Enhanced circulation of river water in the proximity of the beach areas. Coupled with high rate disinfection of the circulation water (UV)
2) Build interceptor sewer connected to all outfalls leading to existing WPCP where treatment of dry weather flows would occur.	2) I/I reduction	2) Build interceptor sewer connected to all outfalls and treat stormwater at a) existing WPCP and b) stormwater detention ponds fitted with high rate disinfection capability (e.g. UV reactor).	

Source: "Technical Guidelines for Preparing a Pollution Control Plan", MOE (1987).

Table 5.2 List Of Potential Control Measures

Source	Pollutant Species	Potential Control Measures
CSO	Heavy Metals	1. Retention storage 2. Sewer separation 3. Sewer use controls (reduction of industrial inputs)
CSO	Bacteria	1. High rate disinfection 2. Retention separation 3. Sewer separation
Intermittent	Bacteria	1. Interception and central dry weather treatment 2. Local treatment 3. Elimination of cross-connections

On the occasions when a given pollutant source does not interact with other sources and is the sole source of the pollutant, the control measures for that source do not need to be considered in connection with the formulation of the plan for multi-source problems. This entails the preparation of separate mini-plans for single or non-interactive sources that will be integrated into the plan at a later stage.

Table 5.3 Alternative Pollution Control Plans

Plan A: Wet Weather Bypass Controls

Plan Number	Control Alternatives
A-1	Storage and high rate treatment
A-2	I/I reduction
A-3	A-1 + A-2

Table 5.3 Alternative Pollution Control Plans (cont)

Plan B: Controls for Intermittent Dry Weather Sources and Stormwater Runoff

Plan Number	Control Alternatives
B-1	Disconnection of cross-connections + street sweeping + enhanced circulation including disinfection
B-2	Dry-wet interception including runoff storage/treatment
B-3	Disconnection + enhanced circulation
B-4	Dry/wet interceptor + street sweeping
B-5	Dry/wet interceptor + enhanced circulation

5.3 EVALUATION

Once the list of alternative pollution control plans has been completed the evaluation process is initiated. At this point in the process the decision makers have to select the appropriate evaluation criteria and give weight to their relative importance. The evaluation criteria have to reflect the concerns within the community (eg. water quality, cost and social impact).

There are five general categories that the evaluation criteria should address:

1. *Water Quality*: Does the alternative meet water quality or effluent objectives?

2. *Economic*: What is the total cost of the alternative considering the time value of money (i.e. discounting future outlays)?

3. *Financial:* Where will the funding for the alternative come from?

4. *Environmental*: Will implementing the alternative result in significant environmental impacts (eg. dredge spoil disposal)?

5. *Social*: Will implementing the alternative result in social disruption?

The following sections discuss these categories in some additional detail.

5.3.1 Water Quality

These criteria will be stated as either ambient water quality objectives (PWQOs) or as effluent objectives for given pollutant sources derived from the water quality objectives. Some substances do not have an associated PWQO, therefore MOE staff should be consulted so that any concerns regarding such substances can be identified and suitable interim criteria specified. It is beneficial to translate water quality criteria into effluent criteria, thus facilitating the screening of the alternatives. The effluent criteria data should relate directly to the water quality criteria. Surrogate effluent criteria that do not have specific relationships to water quality should be avoided. A prime example of undesirable surrogate effluent criteria is that of stormwater detention facilities with effluent objectives that are specified as containment of a precipitation event of a given duration and frequency (eg. containment of a 2 hour, 2 year storm). This can be mitigated by building effluent criteria into the design objectives of the stormwater detention facilities. The design objectives should also address the impacts of stormwater bypasses and overflows on the receiving water.

When selecting water quality criteria some consideration should be given to identifying the criteria which best represent any beneficial use(s). In some cases there is no possibility for a particular use to exist (eg. swimming in ship docking areas) then it might be possible to downgrade the weight given to the criteria (indicator bacteria) supporting the particular beneficial use. In other cases the water quality or effluent criteria do not satisfactorily capture the impact upon the beneficial use. The use of mean bacteria density as the water quality criteria for swimming does not give the decision maker an adequate impression of the impact of bacteria upon the availability of swimming (i.e. the number of available swimming days when beaches are not closed). In this case it would be better to use available swimming days as the water quality criteria.

It must be noted that it may not always be feasible to achieve the desired water quality criteria no matter what controls are put in place. In cases such as these the alternative plans should be judged in terms of the degree of water quality improvement they provide. Whenever possible, the highest weighting should go to the alternatives that achieve PWQOs. If more than one screening of alternatives is foreseen then, depending on the nature of the problem, it might be beneficial to use water quality criteria as a first screening measure thereby eliminating all alternatives that do not meet the desired criteria.

5.3.2 Economic

Each alternative plan evaluated will have both capital and operating costs necessary for it's implementation (direct costs). There are several items involved in calculating direct costs:

1. construction and equipment,
2. engineering and contingencies,
3. land, right-of-way, easements,
4. administration,
5. operation and maintenance, and
6. capital replacement where the planning period exceeds the life of the structure(s) and for equipment.

The expenditures associated with each of the alternative plans may not occur with the same timing (eg. some plans may have staged control measures). In these cases the present value of the costs for comparable planning periods should be calculated and used for comparison.

5.3.3 Financial

It should be made clear in the alternative plans where the funding for the implementation of the control measures will be coming from. This will vary depending upon the players involved in a PCP and the types of control measures that need to be implemented. It could include cost-sharing schemes involving municipal, regional and provincial agencies based on programs that are already in place.

5.3.4 Environmental

It has to be determined whether implementing an alternative plan will result in significant environmental impacts. If there are controls in the plan that will cause environmental impacts then it is possible that a class environmental assessment (EA) will have to be conducted. Table 5.4 provides a list of activities proposed by an alternative plan that are subject to the class EA process. These activities are assigned to one of three categories:

1. Schedule A: activities proposed for total exemption
2. Schedule B: activities proposed for exemption subject to screening
3. Schedule C: activities subject to the class EA process

The decision maker(s) has to decide the weighting for alternative plans that involve environmental assessments.

If an environmental assessment is required it is possible to minimize subsequent reporting (in the EA process) if the evaluation of the alternative plans is well documented. Figure 5.3 illustrates the planning and design process for class EA type municipal sewage and water projects. Once the evaluation and screening of the alternative plans has been completed an activity that is required to proceed through the EA process will already have fulfilled the requirements of the first two phrases outlined in Figure 5.3.

Table 5.4 PCP Projects Subject to Class EA Categories

SCHEDULE A: Activities Proposed for Total Exemption

1. Normal and emergency operations activities. Such activities might include, but *are not limited to* the following:
   - modify, repair, reconstruct existing facilities to provide operational, maintenance or other improvements such as: reducing odour; insulating buildings to reduce noise levels and conserve energy; landscaping;
   - on-going maintenance activities;
   - normal operation of sewage treatment plants;
   - installation of new service connections from existing sewers;
   - maintenance and/or minor improvements to grounds and structures;

Table 5.4 (cont)

- addition of minor buildings, sheds and storage areas;
- repairs, cleaning, renovations or replacement of sewage treatment facilities, pumping plant equipment, or outfalls;
- cleaning and/or relining existing collection systems;
- repairs and renovations to existing collection system and/or appurtenances; • increasing pumping station capacity by adding or replacing equipment and appurtenances where new equipment is located within an existing shell or housing structure;
- installation or replacement of standby power equipment where new equipment is located within an existing shell or housing structure.

2. Expand sewage treatment plant up to existing rated capacity where no new land is required.

3. Install chemical or other process equipment; provide additional treatment facilities in existing lagoons, such as aeration, chemical additions, post treatment; construct associated facilities in existing pumping stations.

4. Replace individual septic systems with alternative individual treatment plants.

5. Expand buffer zone between lagoon facility or land treatment area and adjacent uses.

6. Dispose, utilize, or manage on an interim basis (e.g. further treatment of sludge at drying beds, composting, temporary holding at transfer station), sludge at an existing sewage treatment plant where the sludge is generated; or at an existing landfill, incineration or organic soil conditioning site,where the sludge is to be utilized or disposed of.

7. Establish sewage collection system and all necessary works to connect the system to an existing sewage or natural drainage outlet, provided all such facilities are to be located in road allowances clearly shown on approved development plans and/or utility corridors clearly shown on approved development plans.

8. Establish a new sludge organic soil condition site.

Table 5.4 (cont)

SCHEDULE B: Activities Proposed for Exemption Subject to Screening

1. Establish sewage collection system in existing road allowance, wherein there exists a road which is currently being used to carry vehicular traffic for at least three seasons of the year, or a utility corridor, where there exists a utility.

2. Establish sewage collection system not in a road allowance shown on approved development plans nor in a utility corridor shown on approved development plans.

3. Construct new stormwater retention and detention ponds.

4. Increase size of existing communal septic tank or tile field at substantially the same location.

5. Extend, enlarge or add additional outfall in existing receiving waters.

6. Add flow equalization tankage at existing sewage treatment plant for influent and/or effluent control.

7. Establish interim sludge management facilities at: a sewage treatment plant where the sludge was not generated; or an existing landfill, incineration or organic soil conditioning site where the sludge is not to be disposed of nor utilized.

8. Retire (e.g. demolition, abandonment, decommission, etc.) a sewage facility, which facility was subject to the Act for its establishment.

9. Increase pumping station capacity by adding or replacing equipment and appurtenances where new equipment is located in a new structure.

10. Installation or replacement of standby power equipment where new equipment is located in the new structure.

11. Expand sewage treatment plant up to existing rated capacity where land is required.

SCHEDULE C: Activities Subject to the Class EA Process

1. Construct new sewage system.

2. Establish sewage collection system not in existing road allowance or existing utility corridor.

3. Expand existing sewage treatment plant beyond existing rated capacity.

Table 5.4 (cont)

4. Add additional lagoon cells to an existing sewage system.

5. Establish an outfall in a new receiving water body.

6. Provide for land application of effluent through spray irrigation system or overland flow.

7. Dispose of, utilize or manage sludge on an interim basis at a new sludge landfill site or new sludge incineration site.

8. Manage sludge at a transfer station or storage lagoon not located at a sewage treatment plant, incineration site, landfill site, nor organic soil conditioning site.

5.3.5 Social

This is much the same as the environmental category except that it is the impact of the activity on the social community that is addressed. This is usually incorporated into the EA process (if necessary). Social impacts ordinarily are given a low weight in the evaluation process as the impacts are usually only temporary in nature.

5.3.6 Overview

Table 5.5 lists the evaluation criteria, weights and target values for the example that was illustrated in Section 5.2. The number of criteria used for water quality will vary depending upon the pollutant species, pollutant sources, and the desired level of control.

Figure 5.3 Planning and Design Process for Class EA Type Municipal Sewage and Water Projects

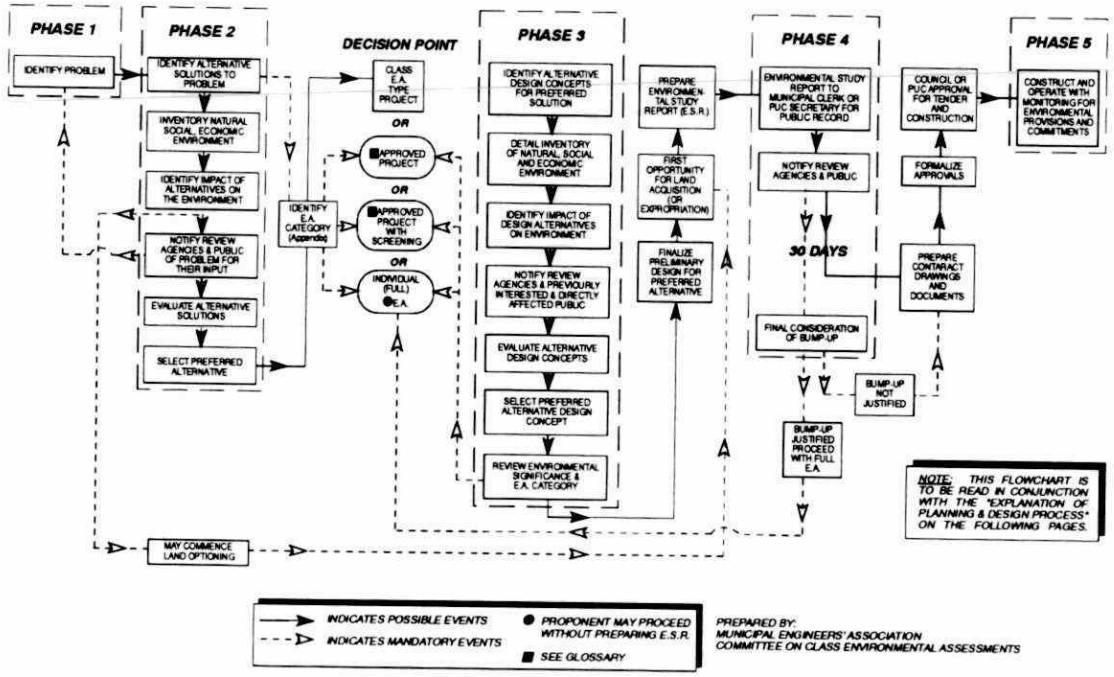

PHASE 1
IDENTIFY PROBLEM
PHASE 2
IDENTIFY ALTERNATIVE SOLUTIONS TO PROBLEM
INVENTORY NATURAL SOCIAL ECONOMIC ENVIRONMENT
IDENTIFY IMPACT OF ALTERNATIVES ON THE ENVIRONMENT
NOTIFY REVIEW AGENCIES & PUBLIC OF PROBLEM FOR THEIR INPUT
EVALUATE ALTERNATIVE SOLUTIONS
SELECT PREFERRED ALTERNATIVE
IDENTIFY E.A. CATEGORY (Agenda)
DECISION POINT
CLASS E.A. TYPE PROJECT
OR
APPROVED PROJECT
OR
APPROVED PROJECT WITH SCREENING
OR
INDIVIDUAL (FULL) E.A.
PHASE 3
IDENTIFY ALTERNATIVE DESIGN CONCEPTS FOR PREFERRED SOLUTION
DETAIL INVENTORY OF NATURAL, SOCIAL AND ECONOMIC ENVIRONMENT
IDENTIFY IMPACT OF DESIGN ALTERNATIVES ON ENVIRONMENT
NOTIFY REVIEW AGENCIES & PREVIOUSLY INTERESTED & DIRECTLY AFFECTED PUBLIC
EVALUATE ALTERNATIVE DESIGN CONCEPTS
SELECT PREFERRED ALTERNATIVE DESIGN CONCEPT
REVIEW ENVIRONMENTAL SIGNIFICANCE & E.A. CATEGORY
PREPARE ENVIRONMENTAL STUDY REPORT (E.S.R.)
FIRST OPPORTUNITY FOR LAND ACQUISITION (OR EXPROPRIATION)
FINALIZE PRELIMINARY DESIGN FOR PREFERRED ALTERNATIVE
PHASE 4
ENVIRONMENTAL STUDY REPORT TO MUNICIPAL CLERK OR PUC SECRETARY FOR PUBLIC RECORD
NOTIFY REVIEW AGENCIES & PUBLIC
30 DAYS
FINAL CONSIDERATION OF BUMP-UP
BUMP-UP NOT JUSTIFIED
BUMP-UP JUSTIFIED PROCEED WITH FULL E.A.
COUNCIL OR PUC APPROVAL FOR TENDER AND CONSTRUCTION
FORMALIZE APPROVALS
PREPARE CONTRACT DRAWINGS AND DOCUMENTS
PHASE 5
CONSTRUCT AND OPERATE WITH MONITORING FOR ENVIRONMENTAL PROVISIONS AND COMMITMENTS
MAY COMMENCE LAND OPTIONING
NOTE: THIS FLOWCHART IS TO BE READ IN CONJUNCTION WITH THE "EXPLANATION OF PLANNING & DESIGN PROCESS" ON THE FOLLOWING PAGES.
INDICATES POSSIBLE EVENTS
INDICATES MANDATORY EVENTS
PROPONENT MAY PROCEED WITHOUT PREPARING E.S.R.
SEE GLOSSARY
PREPARED BY:
MUNICIPAL ENGINEERS' ASSOCIATION
COMMITTEE ON CLASS ENVIRONMENTAL ASSESSMENTS

Table 5.5 Evaluation Criteria for the Hypothetical Example.

Group	Weight	Criteria	Target Value
Water Quality	High	WQ1: Elimination of untreated sewage discharges in dry weather	Zero inc.
	High	WQ2: Elimination of untreated sewage discharges in wet weather	Zero inc.
	High	WQ3: Exceedance frequency of fecal coliform densities of 100 org/dL	10%
Economic	High	E1: Present value of abate plant cost	Min.
Equitable Distribution of Costs	High	D1: $/person in communities A and B for control of common fecal coliform sources	None
Financial Feasibility	Med.	F1: Ratio new debt/total debt for community A	None
		F2: Ratio new debt/total debt for community B	None
Social Impacts	Low	S1: Community disruption by construction activity associated with implementing alternative	None
Ease of Implementation	Low	I1: Public acceptance of alternative	Min. opp.
Environmental Impacts	Med.	EI1: Impact upon natural environment of implementing alternative	Min.

5.3.7 Evaluation of Plan Performance

Once the evaluation criteria have been identified and alternative pollution control plans developed, plan performance with respect to each of the criteria is assessed. The present state of water quality or effluent loading is usually defined in the performance

assessment by the inclusion of a "do nothing plan". The "do nothing plan" also serves as a benchmark against which the performance of the other plans are assessed. The "do nothing" option should also be evaluated for the conditions that will exist at the end of the planning period so that any changes in the nature of existing impacts with time are identified.

The assessment of the plan performance for water quality criteria will usually require some form of modelling. All proposed alternative plans require evaluation, therefore judgement should be exercised when formulating plans so that only those with some potential for meeting the criteria are included. Economic, social and environmental criteria will also require an assessment for each of the plans.

The evaluation process should be structured so that the problem statement and potential control measures are outlined upfront. Once this has been stated the alternative pollution control plans should be listed and evaluation criteria established. The plan evaluation should address all items described in the problem statement. The data is then entered into a plan performance evaluation matrix. From this the alternatives undergo a screening process.

5.4 SCREENING

Once a plan performance evaluation has been completed the results are entered into a matrix that is illustrated in Table 5.6. The first column represents a listing of all the alternative plans that underwent evaluation. The evaluation criteria are first weighted according to their relative importance and then aggregated into groups of equal importance (high, medium, low). The decision of where to place the various criteria should be made at the working level, allowing for a review by other interested parties.

The next stage involves detailed analyses to determine the individual elements of the matrix (for each alternative, to estimate the value of or impact upon each of the criteria). Once this has been completed the next step is to identify the dominant alternative(s).

Table 5.6 Preliminary Screening Matrix.

	HIGH IMPORTANCE CRITERIA	MEDIUM IMPORTANCE CRITERIA	LOW IMPORTANCE CIRTERIA
LIST OF ALTER-NATIVES			
1.	.....	.....	.....
2.	.....	.....	.....
3.	.....	.....	.....
.			
.			
.			
N	.....	.....	.....

Note: Entries in the matrix may be qualitative descriptions (e.g. very large, large, medium, small, very small).

The identification of the dominant alternative(s) is a two phase approach:

1. Each of the alternatives is marked in numerical order (e.g. 1, 2, 3...) with respect to each of the individual evaluation criteria. Where two alternatives are equal, they are assigned identical ranks. A new matrix consisting of just the rankings of the alternatives is then prepared.

2. Pairs of alternatives are then compared to select the preferred alternative from each pair. By examining successive pairs, a rank ordering of the total array of alternatives is thus established. Emphasis in the pairwise comparison is focused on the "high" importance criteria but in the event of an apparent tie (or close to a tie), attention is then focused on "medium" importance criteria and so on.

This process will be explained in further detail using the case study that was outlined in Section 5.2 (refer to Figure 5.2, Tables 5.1, 5.2, and 5.3).

The alternatives for this case study were divided into two separate plans. Table 5.3 lists the alternative plans for wet weather bypass controls (Plan A) and controls for intermittent dry weather

sources and stormwater runoff (Plan B). The evaluation of the alternatives in Plan A (based on continuous simulation analysis) resulted in the selection of Plan A-3 as the "best" plan since it was the most cost-effective. It was possible to identify the "best" plan considering only performance and cost since other factors such as financial feasibility, social impact, etc. did not play a large role in the evaluation. The cost of Plan A-3 ($750K) has to be added to the cost of all other control measures required from community B. This will allow for the total economic impact upon community B to be gauged.

Table 5.7 lists the results from the evaluation of the alternatives for Plan B. Wherever possible numeric values were used, however, more subjective evaluations assessing social and environmental impacts and ease of implementation are also included. Each of the plans is ranked for each of the individual evaluation criteria. This allows for the numeric and subjective values contained in Table 5.7 to be replaced by the individual rank value (Table 5.8).

Table 5.7 Assessment Matrix for Case Study

ALTER-NATIVE	HIGH				MEDIUM			LOW	
	DRY WEATHER DIS-CHARGE	FREQ. OF EXCEED ANCE 100 org/dL	P.V. TOTAL COSTS $K	EQUITY $/ PERSON	FINANCIAL FEASI-BILITY A	FINANCIAL FEASI-BILITY B	ENVIRON-MENTAL IMPACT	SOCIAL IMPACT	EASE OF IMPLEMEN-TATION
B-1	None	5%	$ 750	A = $25 B = $67	0.45	0.23	V. Low	Med	High
B-2	None	10%	$3,000	A = $100 B = $26.7	.180	.090	High	Med	Med
B-3	None	7%	$ 650	A = $21 B = $5.9	.038	.020	V. Low	Low	High
B-4	None	9%	$3,100	A = $102 B = $27.7	.184	.094	High	Med	Med
B-5	None	3%	$3,400	A = #115	.210	.101	High	Med	Med

1) Ratio $\frac{\text{New Debt}}{\text{Total Debt}}$ Source: "Technical Guidelines for Preparing a Pollution Control Plan", (MOE (1987))

Table 5.8 Ranking for Case Study

ALTER-NATIVE	HIGH				MEDIUM			LOW	
	DRY WEATHER DISCHARGE	FREQ OF EXCEED-ENCE 100 org/dL	P.V. TOTAL COSTS $K	EQUITY $/ PERSON	FINANCIAL FEASI-BILITY A	FINANCIAL FEASI-BILTY B	ENVIRON-MENTAL IMPACT	SOCIAL IMPACT	EASE OF IMPLEMEN TATION
B-1	1	2	2	2	2	2	1	2	1
B-2	1	5	3	2	3	3	2	2	2
B-3	1	3	1	1	1	1	1	1	1
B-4	1	4	4	2	4	4	2	2	2
B-5	1	1	5	3	5	5	2	2	2

Source: "Technical Guidelines for Preparing a Pollution Control Plan", (MOE, 1987).

The final step in the screening procedure is to conduct a pairwise comparison of the alternative plans. The dominant ("best") plan from each pairing advances through this process until the "best" plan is identified (the poorer plan from each of the pairings is eliminated from the process). This procedure is illustrated in Table 5.9 using the alternatives for Plan B. In this case, four pairwise comparisons were made which resulted in the selection of plan B-3 as the "best" plan.

Table 5.9 Dominance Evaluation for Case Study

ALTER-NATIVE	HIGH				MEDIUM			LOW	
	DRY WEATHER DISCHARGE	FREQ OF EXCEED-ANCE 100 org/dL	P.V. TOTAL COSTS $K	EQUITY $/ PERSON	FINANCIAL FEASI-BILITY A	FINANCIAL FEASI-BILITY B	ENVIRON-MENTAL IMPACT	SOCIAL IMPACT	EASE OF IMPLEMEN-TATION
First Pairwise Comparison:									
B-1	1.5	1	1	1.5	1	1	1	1.5	1
B-2	1.5	2	2	1.5	2	2	2	1.5	2
Conclusion: B-1 DOMINANT									
Second Pairwise Comparison:									
B-1	1.5	1	2	2	2	2	1.5	2	1.5
B-3	1.5	2	1	1	1	1	1.5	1	1.5
Conclusion: B-3 DOMINANT									
Third Pairwise Comparison:									
B-3	1.5	1	2	1	1	1	1	1	1
B-4	1.5	2	1 2	2	2	2	2	2	
Conclusion: B-3 DOMINANT									
Fourth Pairwise Comparison:									
B-3	1.5	2	1	1	1	1	1	1	1
B-5	1.5	1	2	2	2	2	2	2	2
Conclusion: B-3 OVERALL DOMINANT									

Select Plan B-3: Disconnection of cross-connections plus enhanced in-stream circulation with disinfection.

Source: "Technical Guidelines for Preparing a Pollution Control Plan", MOE, 1987.

5.5 SUMMARY REPORT

Once the screening procedure has been completed and the "best" plan selected the PCP Summary Report is prepared. The purpose of the report is to document the problem analysis and the rationale that led to the selection of the "best" plan. The report should contain the following:

- problem description including a description of the study area;
- statement of pollution control and other objectives;
- description of the evaluation criteria used for screening alternative plans;
- description of alternative plans; and
- presentation of preferred management strategy including specifics of which party(s) will carry out the management actions.

The results from the detailed technical analysis and the detailed descriptions of the control alternatives should be presented in separate technical reports or in appendices to the Summary Report.

5.6 CONCLUSIONS

In summary, the objectives of a PCP study are:

1. to define the cost-effective, environmentally and socially acceptable measures which will achieve the necessary levels of control over water-borne pollutant discharges from municipal, industrial and agricultural sources in order to protect beneficial water use;

2. to provide a framework which will facilitate municipal, industrial and agricultural pollution control planning and enable a greater degree of integration with other municipal planning and contemporary water management and planning processes; and

3. to enable the Ministry to make optimum allocation of capital funds for assisting the provision or upgrading of municipal wastewater conveyance and treatment facilities and drainage works.

In order to meet the above objectives a cursory and/or detailed assessment is carried out. The results from the Assessment(s) provide the basis from which alternative pollution control plans are formulated. In order to assess the alternative plans evaluation criteria have to be established. The criteria have to address five general categories: water quality (ambient and/or effluent), economic, financial, environmental impact and social impact. The alternative plans are analyzed based on the evaluation criteria that is selected by the decision maker(s).

The results from the evaluation phase are then compiled in matrix format for the two phased screening procedure. In the first phase the alternative plans are ranked with respect to each of the individual evaluation criteria. This results in a new matrix that displays the rank for each evaluation criteria for all of the alternative plans. The second phase involves the pairwise comparison of the alternatives until the "best" plan is identified.

The entire PCP process is then documented in a Summary Report. The report explains in detail the methodology behind the selection of the "best" plan and the plan itself and outlines the implementation of the plan.

CHAPTER 6

The Intricacies of Wet-Weather Flows and Modelling.

Miguel Medina Jr.

6.1 INTRODUCTION

Urban stormwater runoff processes can be subdivided into three major subsystems: (1) overland flow, (2) storage and transport through natural or engineered drainage conduits, and (3) receiving water transport. Successful receiving water quality modelling is highly dependent upon our ability to describe mathematically pollutant accumulation, surface washoff and other transport mechanisms occurring before discharge to the receiving subsystem. Because of the random nature of storm events, it is appropriate to analyze water quality effects within a probabilistic setting: this can be accomplished by long-term simulation with *physically-based* models, *statistically-based* approaches (e.g. derived distribution methods) or a combination of both techniques. The probabilistic models are particularly dependent on how well the distributions of the original variables can be hypothesized. The physically-based models are highly dependent on the input variable time series, which includes parameters that may have been estimated from available data by statistical procedures. A more detailed review of the theoretical basis and state-of-the-art in water quality modelling has been presented elsewhere (Medina, 1986).

The scope of this paper is limited to: (1) quantitative analysis of the rainfall time series that generates the runoff events, (2) overland flow, pollutant accumulation and washoff, and (3) storage and transport through natural or engineered devices. The objectives are

to review the role that mathematical models can play in the development of urban pollution control plans, present examples of opportunities to combine the advantages of both physically-based and statistically-based approaches into single applications, and any limitations thereof. There are always inadequacies in existing data sources and financial resources for field investigations, and more often than not severe time constraints within which decisions must be made. Yet, it is precisely under these difficult circumstances that simulation models can be most useful, particularly in *evaluating alternatives.*

6.2 ANALYSIS OF RAINFALL TIME SERIES

The large number of factors that affect the quality of surface runoff (buildup between storms, washoff, transport, kinetic interactions, etc.) prevents the use of any single event (either synthetic or historical) for proper analysis and design. It is the frequency response of the system which is significant, and also duration (for receiving water violations). Thus, long-term historical rainfall data are required (e.g. hourly or shorter-interval precipitation for 30 to 40 years is desirable). The purpose in quantitative analysis of the rainfall time series is to summarize the variables of interest (volume, duration, intensity and time between storm events) and statistically characterize the rainfall record to determine seasonal trends.

In addition to seasonal variations, the frequency distribution of variables such as depth (volume) is important in order to assess the probability of occurrence of storm events of various magnitudes.

Once a rainfall time series has been thoroughly analyzed, it is practical to select a segment of that series for detailed runoff quantity and quality simulation. The relevant storm statistics of the short segment should be compared to those of the larger set to insure adequate preservation of rainfall characteristics. Thus, the stormwater model will generate a runoff quantity and quality time series reasonably representative of the longer record.

6.3 SURFACE RUNOFF QUANTITY

Kinematic-wave, distributed-routing rainfall-runoff models are commonly used to provide detailed simulation of storm-runoff periods with soil-moisture accounting between storms. Drainage basins are essentially represented as a set of linked overland-flow, channel and reservoir segments *or* a set of subcatchments from which overland flow drains into nodes (manholes) connected by transport elements (pipes, channels, reservoirs, etc.). Reservoir routing is usually accomplished by the modified Puls method, or an equivalent level pool routing procedure. Kinematic wave theory is used for routing flows over contributing overland-flow areas and through channels (with a linear approximation for circular, pipe segments). The solution to overland-flow problems is much simplified from the St. Venant equations to:

$$\frac{\partial y}{\partial t} + \frac{\partial q}{\partial x} = i - f \qquad (1)$$

$$q = \alpha y^m \qquad (2)$$

Any wavelike behaviour must enter through the continuity equation and the approach precludes changes in surface profile due to dynamic variations. The corresponding set of equations for stream segments, or *channelled* flows, to which the only significant inputs are continuous along the stream axis and consist of rainfall, infiltration, and overland flow is

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q_i \qquad (3)$$

$$Q = \alpha_s A^{m_s} \qquad (4)$$

where

Q	=	discharge rate, say cfs (m^3/sec)
A	=	flow cross-sectional area, say ft^2 (m^2)
q_i	=	continuous lateral inflow rate of overland flow, say cfs/ft (m^2/sec)
q	=	flow rate, say cfs (m^3/sec)
x	=	longitudinal distance, say ft (m)
t	=	time, say seconds
α_s, m_s	=	kinematic parameters for stream segments,
i	=	rainfall intensity, say ft/sec (mm/sec)
f	=	infiltration rate, say ft/sec (mm/sec)
y	=	depth of flow, say ft (m), and
α, m	=	kinematic parameters for overland-flow.

Typically, for turbulent flow in overland-flow segments

$$\alpha = \frac{c}{n}\sqrt{S_o} \qquad (5)$$

and $m = 5/3$

where

n	=	Manning's roughness
c	=	1.49 for English units and 1.0 for metric units, and
S_o	=	slope.

The value of $m_s = 3/2$ is a good approximation for small streams. However, equation (4) may be replaced by the classical Manning relationship:

$$Q = \frac{c}{n} R^{2/3} A \sqrt{S_o} \qquad (6)$$

where R = hydraulic mean radius.

6.4 SURFACE RUNOFF QUALITY

Perhaps the *least* deterministic aspect of water quality modelling is the procedure for computation of surface runoff quality, from assumptions made of pollutant accumulation and washoff processes. These are, generally, that: (1) the amount of pollutant which can be removed during a storm event is dependent on rainfall duration and initial quantity of pollutant *available* for removal; (2) no pollutants decay due to chemical changes or biological degradation during the runoff process, and (3) the amounts of pollutants percolating into the soil by infiltration are not significant. Most field data consist of measurements of stage (converted to discharge through a rating curve) and pollutant concentrations *at the subcatchment outlet*. These data represent the combined effects of accumulation, washoff, routing and contributions from rainfall: the pollutant loads may include contributions from different landuse types with different accumulation rates. Nevertheless, the models can still be used to study *relative* impacts of various control alternatives upstream.

Most surface runoff quality models offer either linear, exponential or Michaelis-Menton pollutant buildup formulations (see Figure 6.1), or all of these as options (e.g. SWMM). The exponential decay of solids buildup is typically represented by:

$$p_{n,j,t} = P_{max_{n,j}} \left[1 - e^{-\lambda_{n,j} t}\right] \qquad (7)$$

where

$p_{n,j,t}$	=	loading of pollutant j on subcatchment n at time t , lb/acre (kg/ha),
$p_{max\ n,j}$	=	maximum (asymptotic) loading of pollutant j on subcatchment n , lb/acre (kg/ha),
$\lambda_{n,j}$	=	power exponent coefficient for pollutant j on subcatchment n , day $^{-1}$, and
t	=	accumulation time, days.

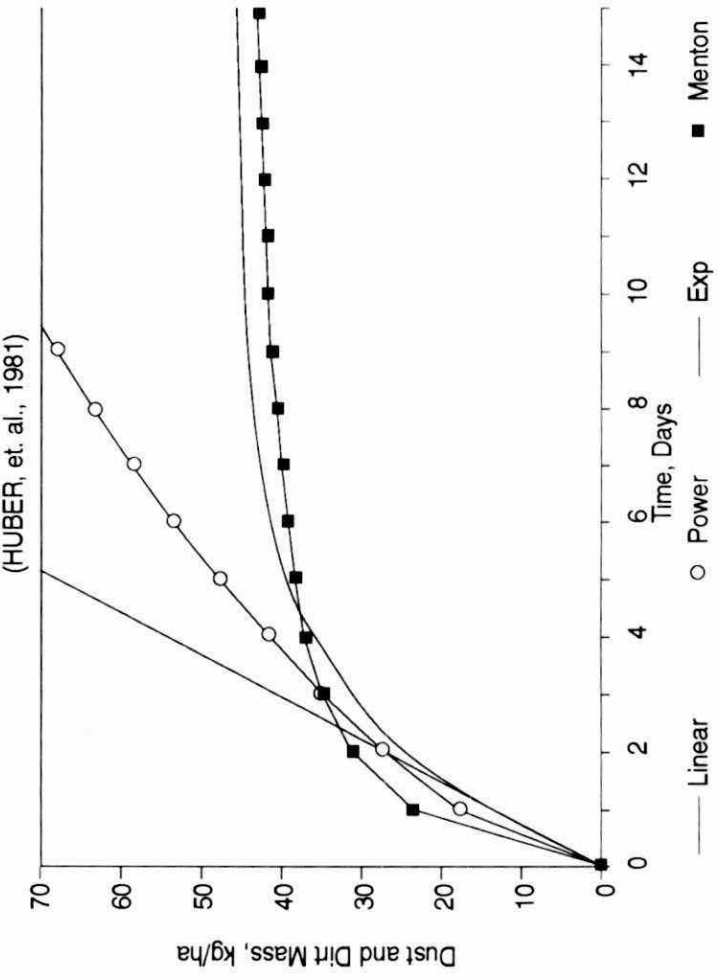


Figure 6.1 Pollutant buildup functions for surface runoff quality computations

The pollutant accumulation process can be related to landuse by specifying a land use type for each subcatchment. Equation (7) is one of the most widely used relationships, as well as the exponential washoff relationship described below.

Washoff, at each time step of simulation, is made proportional to runoff rate:

$$-P_t = \frac{dP}{dt} = -a\, r^b\, P_o \qquad (8)$$

where

P_t	=	pollutant load washed off at time t, lb/sec (kg/sec)
P_o	=	load available for washoff at time t, lb(kg)
r	=	runoff rate, in/hr (mm/hr)
a	=	washoff coefficient, including conversion units, and
b	=	a power constant.

Pollutant transport in overland flow and through both natural and engineered urban storage/treatment systems (pipes, channels, detention basins, etc.) may be represented by the one-dimensional version of the classical advective-dispersive equation (Medina *et al*, 1981):

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left[E\frac{\partial C}{\partial x} - UC\right] \pm \sum S_i \qquad (9)$$

where

C	=	concentration of water quality parameter, (pollutant), M/L^3,
t	=	time, T,
$-E\frac{\partial C}{\partial x}$	=	mass flux due to longitudinal dispersion along the flow axis, the x direction, M/L^2

UC	=	mass flux due to advection by the fluid containing the mass of pollutant, M/L^2T,
S_i	=	sources or sinks of the substance C, M/L^3T,
i	=	1,2,3, . . ., n,
n	=	number of sources or sinks,
U	=	flow velocity, L/T, and
E	=	longitudinal dispersion coefficient, L^2/T,
M	=	mass, L = length, and T = time.

Equation (9) can be applied to *shallow* storage/treatment systems (detention basins, ponds), pipe segments, non-tidal streams, etc. For *deep* storage/treatment systems, a thermal balance is required (Moreno and Medina, 1988). Wet detention pond models are reviewed in the next section due to their importance in urban pollution control planning.

6.5 DETENTION BASIN ROUTING

6.5.1 Deterministic Approach

Pollutants may be routed through a detention basin assuming either complete mixing or plug flow in SWMM (Huber, *et al.*, 1981). The mass balance equation for a well-mixed, variable-volume unit is derived from equation (9) and is given by (Medina *et al.*, 1983):

$$\frac{d(VC)}{dt} = I(t)\ C^I(t) - O(t)\ C(t) - K\ C(t)\ V(t) \qquad (10)$$

where

V	=	reservoir volume , L^3
C^I	=	effluent pollutant concentration, mg/l
C	=	effluent and reservoir pollutant concentration, mg/l
I	=	inflow rate, L^3/t
O	=	outflow rate, L^3/t
t	=	time, and
K	=	first-order decay coefficient, 1/t.

The solution to equation (10) may be approximated numerically over the time step , where subscripts 1 and 2 refer to the beginning and end of the time step :

$$C_2 = \frac{C_1 V_1 + \frac{(C^I_1 + C^I_2)}{2}\Delta t - \frac{C_1 O_1}{2}\Delta t - \frac{K C_1 V_1}{2}\Delta t}{V_2 (1+\frac{K\Delta t}{2}) + \frac{O_2}{2}\Delta t} \qquad (11)$$

The relationship between inflow and outflow rates and volume is known from standard reservoir routing methods and stage-discharge curves specific to the designed detention basin. The concentration in the reservoir at the beginning of the time step, C_1, and the influent concentrations, C^I_1 and C^I_2 are also known as well as the decay rate and time step. In SWMM the product of the decay rate and time step is represented by a removal fraction R obtained from an empirical user-supplied removal equation. Detention basin performance statistics (quantity and quality) may be computed from the outflow time series predicted, for the inflow time series generated by continuous simulation.

6.5.2 Probabilistic Approach

The basic probabilistic methodology was developed by DiToro, refined by DiToro and Small (1979), and adapted to wet ponds (sedimentation devices) and percolation (infiltration, recharge) devices by Driscoll (U.S. EPA, 1986). The long-term average performance is computed from the statistical properties of the detention basin inflows and a few basin design characteristics. Removal due to sedimentation under *dynamic* (flow-through) conditions is given by:

$$R = 1 - \left(1 + \frac{1}{n} \cdot \frac{V_s}{Q/A}\right)^{-n} \qquad (12)$$

where:

R	=	fraction of initial solids removed (R x 100 = % removal).
v_s	=	settling velocity of particles.
Q/A	=	rate of applied flow divided by surface area of basin (an "overflow velocity," often designated overflow rate).
n	=	a parameter which provides a measure of the degree of turbulence or short circuiting, which tends to reduce removal efficiency; typically $1 \leq n \leq 5$, with $n = 3$ for good performance and $n > 5$ for very good performance.

For variable runoff flows that are gamma distributed entering a treatment device and characterized by a mean flow and coefficient of variation (CV_q), the long-term average fraction of total mass removed is:

$$R_L = Z\left[\frac{r}{r - \ln\left[\frac{R_M}{Z}\right]}\right]^{r+1} \qquad (13)$$

where:

R_L	=	long term average fraction removed
R_M	=	fraction removed at mean runoff rate
r	=	$1/CV^2$ (reciprocal of square of CV_q)
CV_q	=	coefficient of variation of runoff flow rates
Z	=	maximum fraction removed at very low rates

Removal under quiescent conditions is very significant since average storm duration in the United States is 6 hours and the average interval between storms is from 3 to 4 days. The volume of a basin relative to the volumes of runoff events routed through

becomes the principal factor in pollutant removal effectiveness. For storm volumes that are gamma distributed, the fraction *not captured*, over all storms, may be represented by:

$$fv = \frac{r_1^{r_1}\ r_2^{r2}}{G\ (r_1)\ G\ (r_2)} \int_{q=0}^{\infty} q^{r_1} \exp\left[\frac{r_2 V}{q}\right] \exp\left[-r_1 q\right]. \tag{14}$$

$$\int_{\Delta=o}^{\infty} \Delta \left[\Delta + \frac{v}{q}\right]^{r_2-1} \exp\left[-r_2\, \Delta\right] d\Delta\, dq$$

where:

r_1	=	$1/CV_q^2$ and $r_2 = 1/CV_d^2$
CV_q	=	coefficient of variation of runoff flow rates
CV_d	=	coefficient of variation of runoff durations
q	=	storm runoff flow rate
Δ	=	average interval between storm midpoints
V	=	basin effective volume, divided by mean storm runoff volume (VE/VR)
$G(r_1)$	=	Gamma function of r_1
f_V	=	fraction of all volumes NOT captured by basin

The double integral cannot be evaluated analytically. A numerical technique using a Laguerre quadrature to approximate the integral with a weighted polynomial is applied. The basic equation transformed for solution using quadratures is:

$$f_v = \frac{r_1^{r_1}\ r_2^{r_2}}{G(r_1)\ G(r_2)} \sum_{k=1}^{m} w_k g\ [x_k] \left[\sum_{j=1}^{m} w_j\, f\ [(X_j, X_k)\right] \tag{15}$$

where:

$$g(x_k) = \left[\frac{x_k}{r_1}\right]^{r_1} \left[\frac{1}{r_1}\right] \exp\left[-r_1 r_2 V/X_k\right]$$

$$f(x_j,x_k) = \left[\frac{x_j}{r_2}\right] \left[\frac{1}{r_2}\right] \left[\frac{x_j}{r_2} + \frac{r_1 V}{x_k}\right]^{r_2-1}$$

m	=	number of orders used in integration
X_j, X_k, W_j, W_k	=	abscissas and weights for Laguerre integration

6.6 INTEGRATED APPROACHES

A review of the design storm concept and its inadequacy in characterizing urban stormwater quality was presented in the proceedings of the last PCP conference (Medina, 1987), where the work of several U.S., Canadian and German investigators was acknowledged. The alternative approaches need not be mutually exclusive; instead, they may be integrated or coupled advantageously. Rainfall data are generally much more widely available than concurrent surface runoff quantity and quality measurements. Under these circumstances, it is particularly useful to combine the physically-based and statistically-based models.

In the absence of site-specific surface runoff data for model calibration, an experienced modeller with accurate rainfall, evaporation, topographic, soils and landuse data can generate a reasonably representative runoff quantity and quality time series with a recognized continuous simulation stormwater management model (such as U.S. EPA SWMM). Published *regional* or *national average* pollutant loads for specific land-use types and percent imperviousness may be used, coupled with *local* climatic and catchment-specific data. Model parameters are subsequently adjusted to yield annual average pollutant loads consistent with experience.

Descriptive statistics of a long-term rainfall record (e.g., means and coefficients of variation of storm event variables such as depth, duration, intensity and time between events) are coupled with wet detention basin design parameters (surface area, average depth, volume, size of permanent pool) to predict long-term average pollutant mass removals. The detention basin performance, as predicted by the statistically-based (gamma-distributed) model described earlier, may be used to adjust the parameters of the physically-based detention model, which is incorporated into SWMM as one of its computational blocks. The combined use of these models is illustrated further with an actual application involving a proposed shopping centre development with a detention basin, evaluated against alternative land uses and pollution control measures for the City of High Point, North Carolina.

6.7 APPLICATION

The city of High Point, North Carolina, is located in the Piedmont region of the State, at the headwaters of the Cape Fear River Basin. The city does not receive water from rivers originating outside its drainage basin; it relies on runoff stored in its two municipal lakes, High Point City Lake and Oak Hollow Lake. Oak Hollow Lake is a secondary water supply source, not subject to the restrictions placed on primary water supplies such as High Point City Lake. A large shopping centre, from which stormwater runoff would drain to Oak Hollow Lake, was proposed by a developer, CBL Associates, Inc. The development would cover an area of about 100 acres (40.5 ha) at close to 90 percent imperviousness, with collected stormwater runoff being routed through a wet detention basin, with outflows passing through a 15 acre (6 ha) buffer zone before draining to the lake.

As a result of discussions held with city of High Point planning and engineering staff, CBL & Associates, Inc., agreed to retain the author for comparative studies of urban stormwater runoff pollution from the proposed CBL Shopping Centre and alternative land uses. Five scenarios were identified, as follows, for stormwater runoff generated from:

1. existing land conditions (designated R-Zoning);

2. CBL & Associates' proposed development with runoff routed through a wet detention pond which would have

   a. a permanent pool with a volume of 1.5 inches (38.1 mm) of runoff, and
   b. a temporary water quality pool with a volume of 1.5 inches (38.1 mm) of runoff and an extended release period of 10 days;

3. development of the site in accordance with existing zoning with runoff being routed through a wet detention pond designed to meet Guilford County regulations;

4. development of the site to meet specifications of the Watershed Protection Ordinance currently being considered by the staff (more restrictive in terms of imperviousness, density of development, designated T-Zoning) without any sort of engineered runoff control; and

5. development of the site to meet specifications of the Watershed Protection Ordinance currently being considered by the staff, with runoff being routed through a wet detention basin designed to meet Guilford County regulations.

6.7.1 Rainfall Analysis

A 40-year record of *hourly* precipitation at nearby Greensboro Airport was obtained from the National Weather Service (NWS) and analyzed. Statistics for storm event durations, intensities, depth (volume), and time between events were computed for each month of the year and for the entire period of record. The statistics for the entire period of record are summarized in Table 6.1.

The cummulative rainfall frequency curve for depth is presented in Figure 6.2. It is important to note that:

1. 90 percent of all storm events of record are less than 1.0 inch (25.4 mm) total depth;
2. 95 percent of all storm events of record are less than 1.5 inches (38.1 mm) total depth; and

Table 6.1: Statistics[1] for Storm Event Variables, 1948-1987

Storm Parameter	Mean	Coefficient of Variation
Depth, in. (mm)	0.420 (10.67)	1.43
Intensity, in/hr (mm/hr)	0.066 (1.68)	1.43
Duration (hrs)	7.477	1.08
Time Between Storms, hrs	86	0.96

[1]Note: NOAA Sta. 3630, Greensboro Airport

Table 6.2 Means of Storm Event Parameters[1]

Historical Record	Duration (hrs)	Intensity in/hr (mm/hr)	Volume in (mm)	Time Between Events (hrs)
1948-1987	7.50	0.066 (1.68)	0.420 (10.67)	86
1974-1975	7.12	0.071 (1.8)	0.445 (11.3)	77

[1]Note: NOAA Sta. 3680, Greensboro Airport

Figure 6.2 Cumulative Rainfall Frequency Curve for Depth, Greensboro Airport

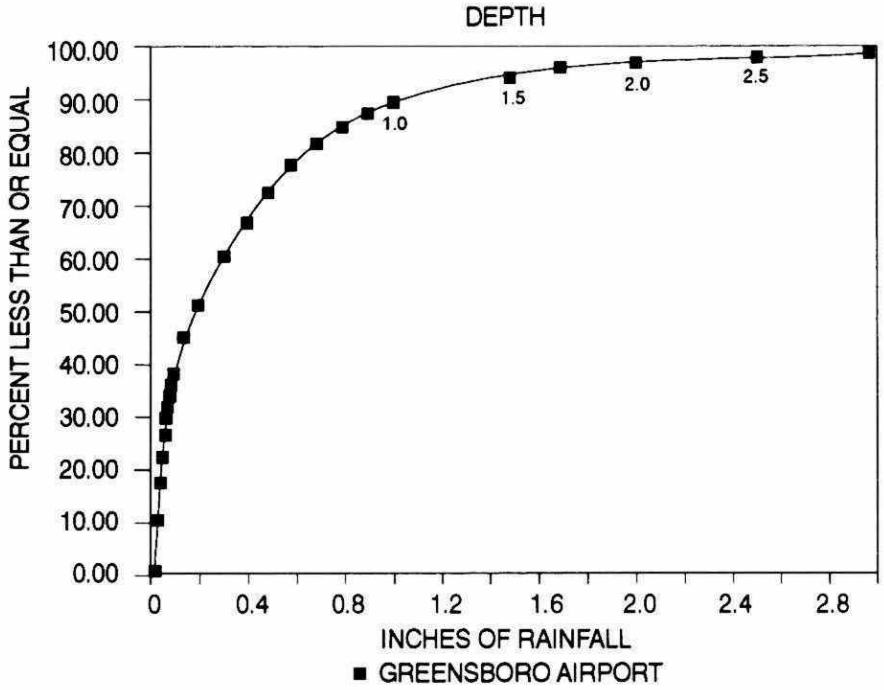
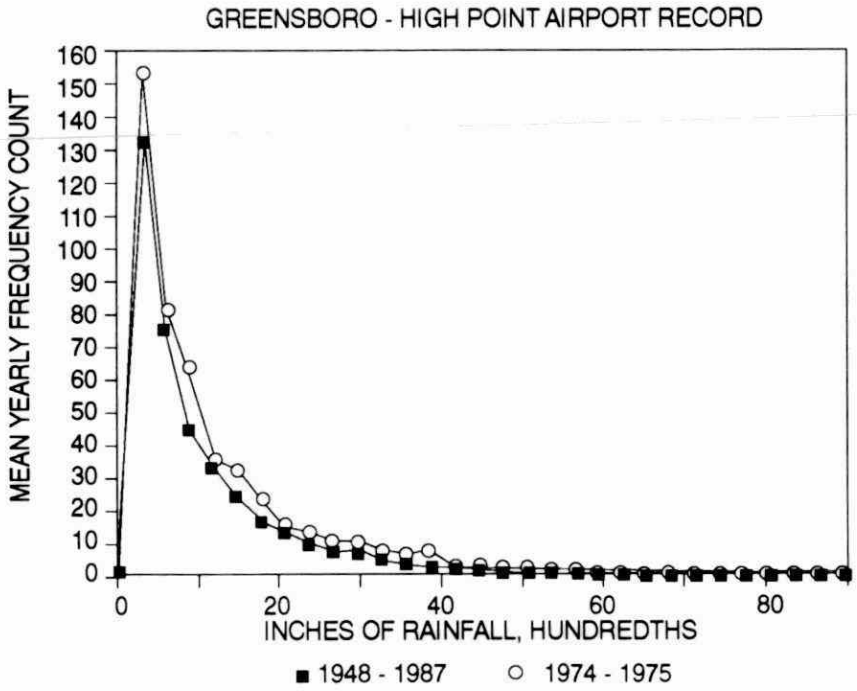


Figure 6.3 Rainfall Depth Frequency Distribution for the Historical Time Series



3. 99 percent of all storm events of record are less than 3.0 inches (76.2 mm) total depth.

The detention facility, as noted above, has been designed to capture 1.5 inches (38.1 mm) of *runoff* in the permanent pool (not including sediment storage) and to detain another 1.5 inches in the temporary water quality pool with an extended release period of 10 days.

A shorter segment of the rainfall record (years 1974 and 1975) was chosen as rainfall input to the continuous simulation model . The mean rainfall depth frequency distributions for the years 1974-1975 and 1948 through 1987 are jointly plotted in Figure 6.3. It is obvious that the distributions are nearly identical. Means of the storm event parameters used to characterize the rainfall historical time series are compared in Table 6.2. The short time series chosen is closely representative of the much longer event time series.

6.7.2 Continuous Simulation

The watershed was discretized into a network of hydraulic elements representing the physical system, for each of the land-use alternatives. Figure 6.4 illustrates the network used to represent the shopping centre. As noted earlier, several mechanisms constitute the essence of stormwater quality, most notably buildup and washoff processes. The contaminants build up on the land surface during dry weather periods preceding storms, and the runoff subsequently washes part of the accumulated material into the natural or engineered drainage system. A number of functional forms (empirical equations) used to simulate these processes have been reviewed. A large number of combinations of different coefficients may be chosen in such a way as to yield the same results (for example, the same annual loads for a particular pollutant). To avoid any controversy, the model was calibrated to yield approximately the same annual loads presented by Schueler (MWCOG, 1987,Table 1.5) according to the appropriate land use percentages and imperviousness for the five scenarios, and for each pollutant selected (total phosphorus, BOD-5, and lead). The loads for agricultural land use were taken from estimates provided by EPA (Meta Systems, March 1976) and Hartigan *et al.* (1982) for active cropland. A linear buildup was chosen for solids accumulation (dust and dirt, DD), with a limiting buildup of 125 lbs. The assumed solids

Table 6.3: Assumed Solids (Dust and Dirt) Buildup Coefficients[1]

Land Use Type	Buildup Coefficient DDFACT (lb/acre/day)
Shopping Center	3.52
R-3 Zoning	1.00
R-5 Zoning	1.77
T-2 Zoning	0.25
T-3r Zoning	1.39
T-3C Zoning	1.39
Agricultural	1.00

[1]NOTE DD = DDFACT (t)
t = time in days

Table 6.4: Calibrated Pollutant Loading Factors[2] (mg/gram of DD)

Land Use Type	Pollutant Type		
	BOD-5	Phosphorus	Lead
Shopping Center	85.6	1.52	0.105
R-3 Zoning	120	1.52	0.123
R-5 Zoning	121	1.52	0.123
T-2 Zoning	108	2.47	0.110
T-3R Zoning	126	1.52	0.099
T-3C Zoning	138	1.66	0.108
Agricultural	175	11.3	0.110

[2]NOTE: The values in this table **must be** used in combination with the assumed values in Table 6.3 and represent the values that yielded the reported annual loads.

buildup coefficients for each land use are summarized in Table 6.3 (these are pollutant-independent values). The calibrated pollutant loading factors are presented in Table 6.4, and must be used in combination with the values in Table 6.3 and the assumed pollutant washoff coefficients and power exponents given below. For example, if a solids buildup rate was initially underestimated, it was adjusted by increasing the pollutant solids fraction to achieve the annual loads reported in the cited literature. The assumed washoff coefficients remained constant for all the simulations :

Pollutant Washoff

Pollutant	Coefficient	Power Coefficient
BOD-5	2.0	0.4
Phosphorus	1.2	0.9
Lead	1.2	0.9

Detention basin performance was calibrated against the percentage removal fractions predicted by the EPA statistical methodology (EPA, 1986), using an overall decay (settling) coefficient K = 0.00001 per time step and the following maximum removal fractions per time step : 0.08 for BOD- 5, 0.17 for phos-phorus, and 0.30 for lead. Particulate fractions for lead of 0.9, 0.67 for total phosphorus and 0.50 for BOD-5, TKN, etc. are reported as typical values, based on the National Urban Runoff Program (NURP) data base, by EPA (1983). Thus, the simulations reflect local climate (rainfall), local terrain parameters, locally engineered storage options (detention), but national pollutant loading and performance criteria.

The following results were obtained for the simulated surface runoff quality per scenario (each of which includes mixed land uses) :

LAND USE SCENARIO	ANNUAL LOAD (lbs) BOD-5	Phosphorus	Lead
Shopping Centre	2860	165	11.4
Previous Zoning (R)	1870	91	7.5
Proposed Zoning (T)	1245	65	4.2
Existing Cond.	1110	139	1.33

6.7.3 Detention Basin Performance

Estimates of the general performance of wet detention ponds from the statistics of the rainfall time series, a runoff coefficient, and basin characteristics (depth, surface area to drainage area ratios, etc.) were computed: the complete methodology is presented in detail elsewhere (EPA, 1986). Average mass removals for total suspended solids, lead, total phosphorus, BOD-5 (and others lumped into the latter group) are presented in Tables 6.5, 6.6, and 6.7 for the shopping centre, previous zoning, and the proposed zoning configurations. The results are plotted in Figure 6.5. The particulate fractions used for these pollutants were noted in the previous section (0.9 for lead, 0.67 for total phosphorus, and 0.50 for BOD-5 and the others).

6.7.4 Comparisons Among Five Scenarios

Three of the scenarios include a detention facility. It is important to note that the Shopping Centre detention facility captures completely 217 out of the 221 storm events in the time series (98 percent of the events); overflow from the temporary water quality pool occurs during 4 events only. The residential detention basins (designed as per Guilford County guidelines) capture 198 out of the 221 events (89 percent); overflow occurs during 23 storm events in the time series. Both loads and flow-weighted concentrations are compared, since we are more interested in loads for limiting nutrients (e.g., phosphorus) and concentrations for organic matter (BOD-5).

Table 6.5: Statistical Wet Detention Model Output for Shopping Center Option

RAINFALL	STATS	MEAN	CV
VOLUME	(inch)	0.420	1.43
INTENS	(in/hr)	0.066	1.43
DURATION	(hr)	7.500	1.08
DELTA	(hr)	86.000	0.95

RUNOFF COEFF	(Rv)	=	0.90
DRAINAGE AREA	(acre	=	100.00
BASIN SURF AREA	(sq ft)	=	139405.00
BASIN DEPTH	(ft)	=	9.25
SHORT CIRC PARAM		=	3.00
OVERFLOW RATE	(QR/A)	=	0.15
VOL CAPAC FACTOR	(VB/VR)	=	9.40

SIZE FRAC	% REMOV DYNAMIC	% REMOV QUIESCENT	% REMOV COMBINED	SETT VELOC	VOL FACTOR
1	1	77	78	0.03	8.39
2	5	79	84	0.30	9.40
3	8	79	88	1.50	9.40
4	9	79	88	7.00	9.40
5	9	79	88	65.0	9.40
AVG	6	79	85		

AVG. TOTAL SUSPENDED SOLIDS REMOVAL	=	85
AVG. TOTAL PHOSPHORUS REMOVAL	=	60
AVG. LEAD REMOVAL	=	77
AVG. TKN, BOD, Cu, Zn REMOVAL	=	43

Table 6.6: Statistical Wet Detention Model Output
for Existing Residential Option

RAINFALL	STATS	MEAN	CV
VOLUME	(inch)	0.420	1.43
INTENS	(in/hr)	0.066	1.43
DURATION	(hr)	7.500	1.08
DELTA	(hr)	86.000	0.95

RUNOFF COEFF	(Rv)	=	0.44
DRAINAGE AREA	(acre)	=	100.00
BASIN SURF AREA	(sq ft)	=	70964.00
BASIN DEPTH	(ft)	=	3.90
SHORT CIRC PARAM		=	3.00
OVERFLOW RATE	(QR/A)	=	0.15
VOL CAPAC FACTOR	(VB/VR)	=	4.13

SIZE FRAC	% REMOV DYNAMIC	% REMOV QUIESCENT	% REMOV COMBINED	SETT VELOC FT/HR	VOL FACTOR VE/VR
1	1	50	51	0.03	3.69
2	5	55	59	0.30	4.13
3	8	55	63	1.50	4.13
4	9	55	63	7.00	4.13
5	9	55	63	65.0	4.13
AVG	6	54	60		

AVG. TOTAL SUSPENDED SOLIDS REMOVAL	=	60
AVG. TOTAL PHOSPHORUS REMOVAL	=	42
AVG. LEAD REMOVAL	=	30
AVG. TKN, BOD, Cu, Zn REMOVAL	=	30

Table 6.7: Statistical Wet Detention Model Output for Proposed Residential Option

RAINFALL	STATS	MEAN	CV
VOLUME	(inch)	0.420	1.43
INTENS	(in/hr)	0.066	1.43
DURATION	(hr)	7.500	1.08
DELTA	(hr)	86.000	0.95

RUNOFF COEFF	(Rv)	=	0.33
DRAINAGE AREA	(acre)	=	100.00
BASIN SURF AREA	(sq ft)	=	70964.00
BASIN DEPTH	(ft)	=	3.90
SHORT CIRC PARAM		=	3.00
OVERFLOW RATE	(QR/A)	=	0.11
VOL CAPAC FACTOR	(VB/VR)	=	5.50

SIZE FRAC	% REMOV DYNAMIC	% REMOV QUIESCENT	% REMOV COMBINED	SETT. VELOC FT/HR	VOL FACTOR VE/VR
1	1	62	63	0.03	5.02
2	6	65	71	0.30	5.50
3	9	65	74	1.50	5.50
4	9	65	74	7.00	5.50
5	9	65	74	65.0	5.50
AVG	7	64	71		

AVG. TOTAL SUSPENDED SOLIDS REMOVAL	=	71
AVG. TOTAL PHOSPHORUS REMOVAL	=	50
AVG. LEAD REMOVAL	=	64
AVG. TKN, BOD, Cu, Zn REMOVAL	=	35

Total annual loads for the five scenarios and three pollutants (representing heavy metals, nutrients and organic matter) are presented in Figures 6.6 through 6.8. The Shopping Centre with detention does an excellent job in reducing lead and phosphorus loads, but does not compare favourably for BOD-5 loads. The event mean concentrations (EMC) are presented in Figures 6.9 through 6.11; the Shopping Centre option ranks the best for phosphorus and second best for lead. The entire concentration frequency distributions (a much better index than EMC's) are presented in Figures 6.12 through 6.14. These figures confirm that the Shopping Centre option does very well for phosphorus and lead, and is not significantly different from the other options for BOD-5 concentration except for existing conditions.

6.7.5 Public Hearings

The results were presented before three public hearings. In a 6 to 3 vote, the City Council approved re-zoning of the property to allow the Shopping Centre development (with detention pond). Clearly, the mathematical models played a key role in evaluating the landuse alternatives and pollution control options.

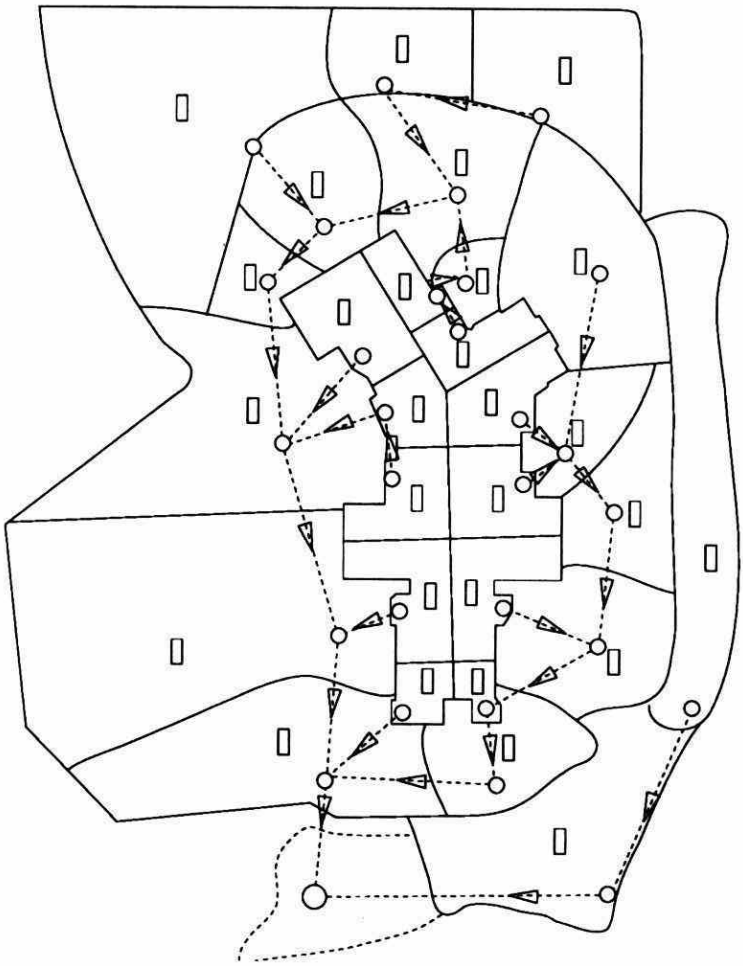


Figure 6.4 Watershed Discretization into Network of Hydraulic Elements

Figure 6.5 Detention Basin Performance as Predicted by the Statistical Methodology

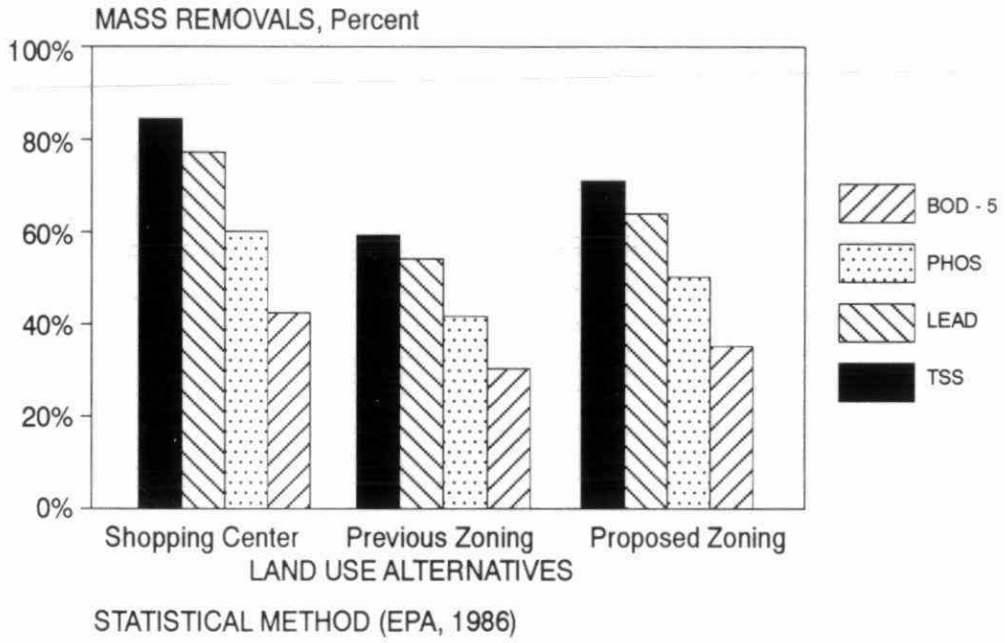
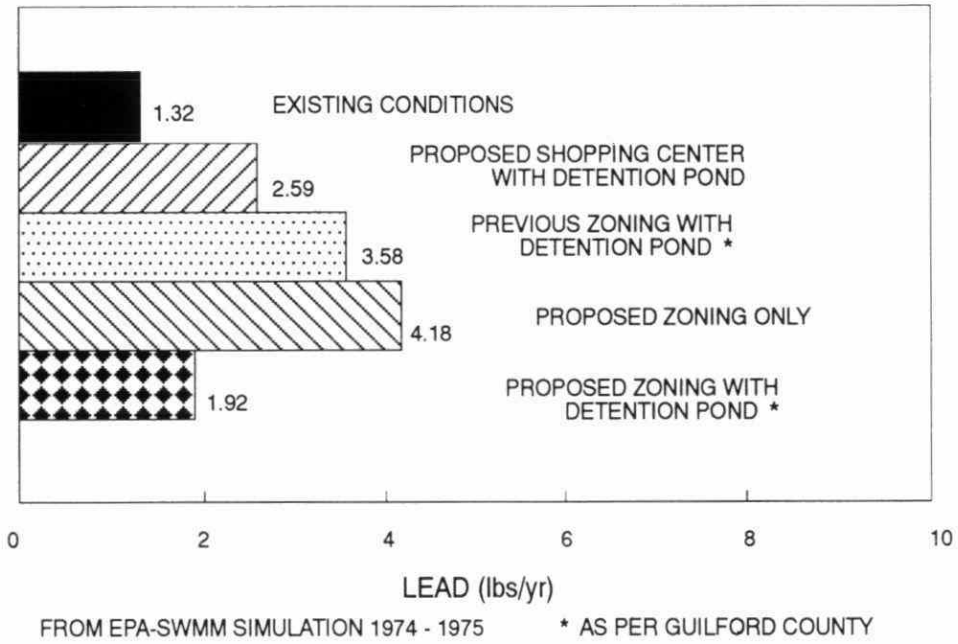


Figure 6.6 Simulated Annual Lead Loads for the Five Scenarios



FROM EPA-SWMM SIMULATION 1974 - 1975 * AS PER GUILFORD COUNTY

Figure 6.7 Simulated Annual Phosphorus Loads For the Five Scenarios

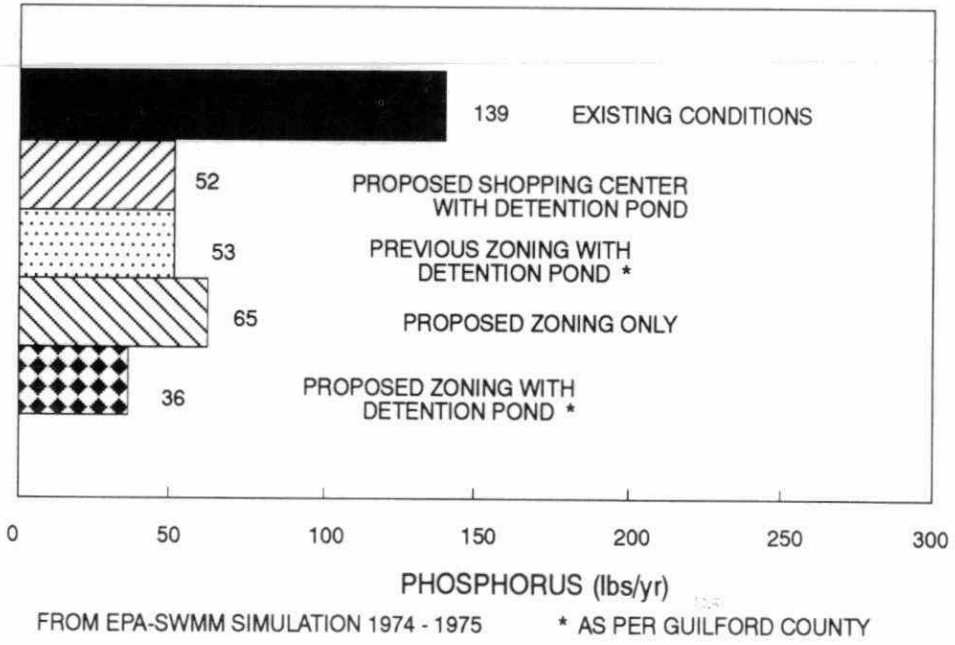


Figure 6.8 Stimulated Annual BOD-5 Loads for the Five Scenarios

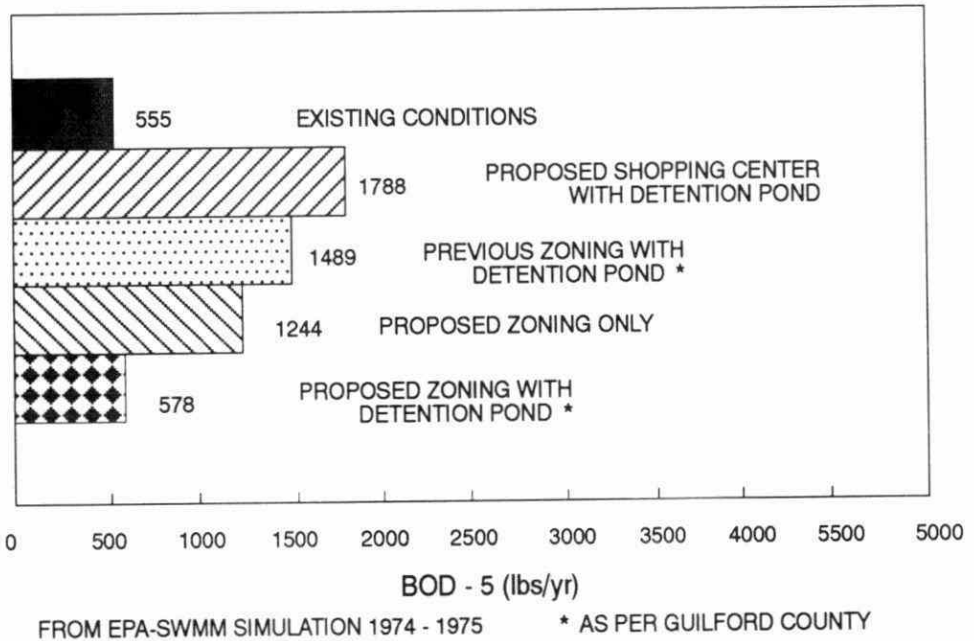
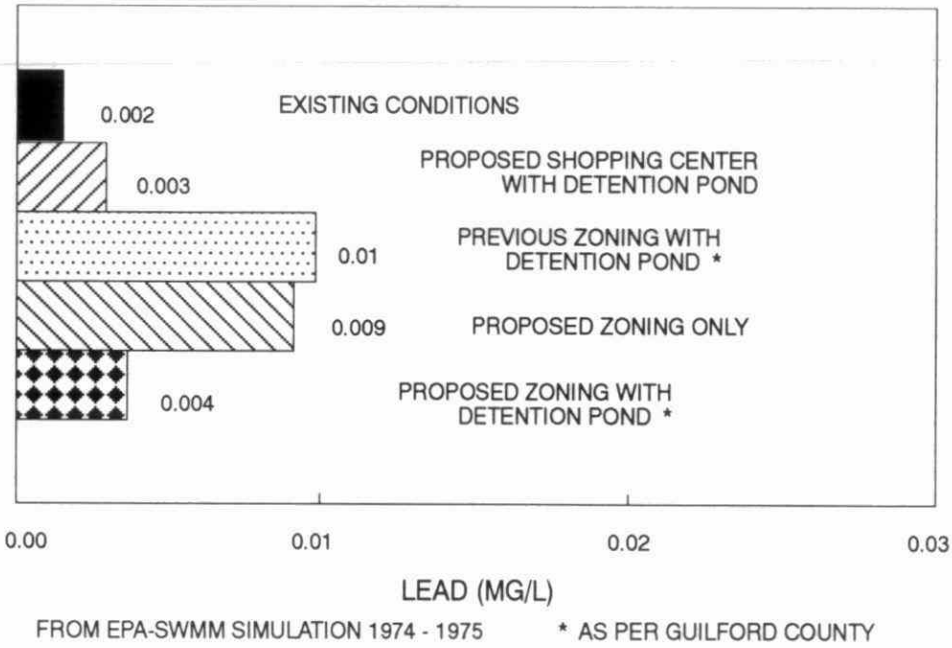


Figure 6.9 Lead Event Mean Concentrations for the Five Scenarios



FROM EPA-SWMM SIMULATION 1974 - 1975 * AS PER GUILFORD COUNTY

Figure 6.10 Phosphorus Event Mean Concentrations for the Five Scenarios

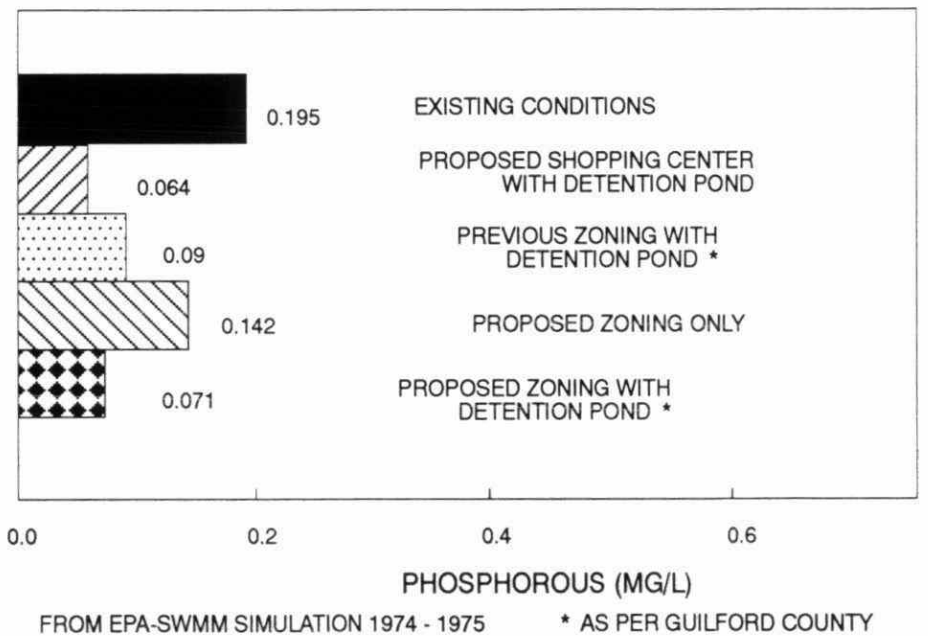
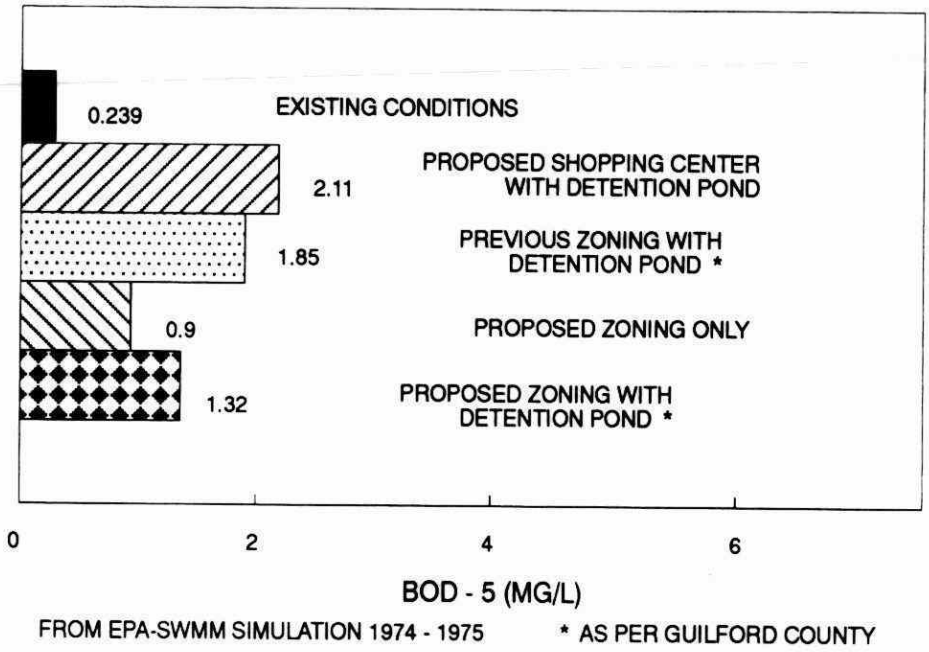


Figure 6.11 BOD-5 Event Mean Concentrations for the Five Scenarios



FROM EPA-SWMM SIMULATION 1974 - 1975 * AS PER GUILFORD COUNTY

Figure 6.12 Lead Concentration Frequency Distribution for the Five Land-Use Alternatives

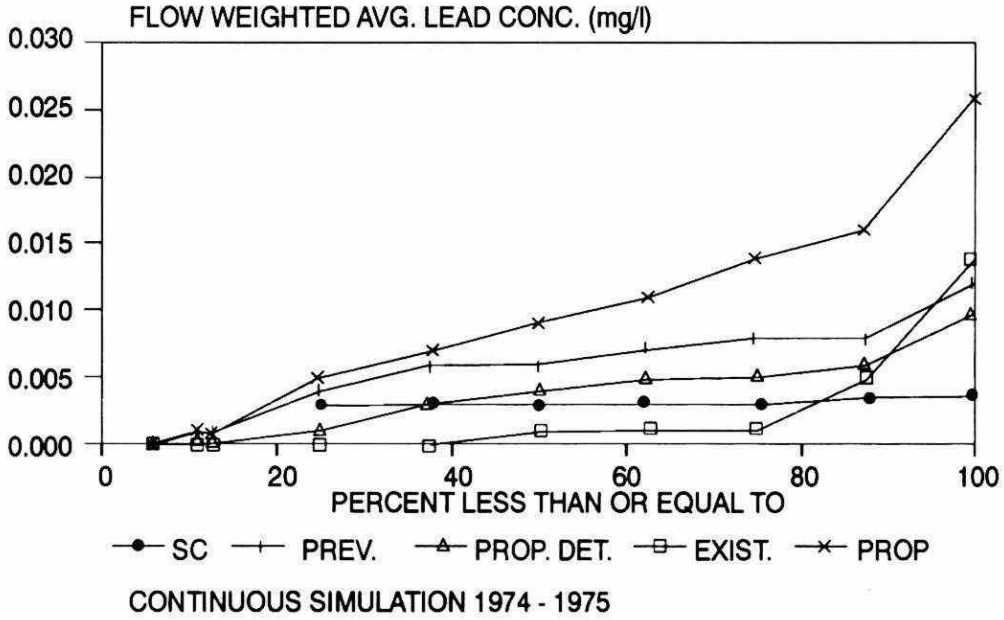


Figure 6.13 Phosphorus Concentration Frequency Distributions for the Five Land-Use Alternatives

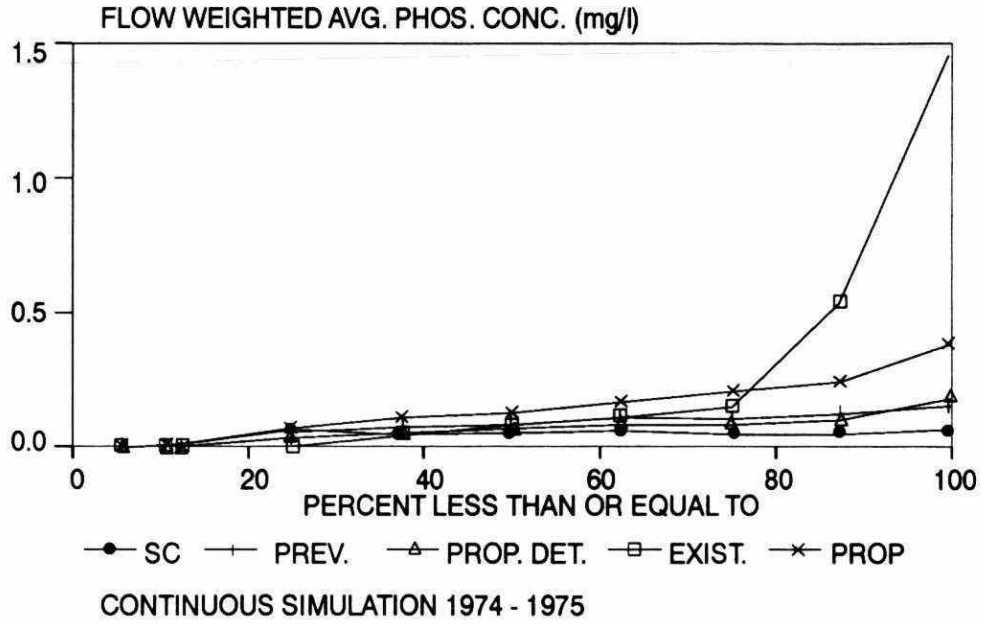
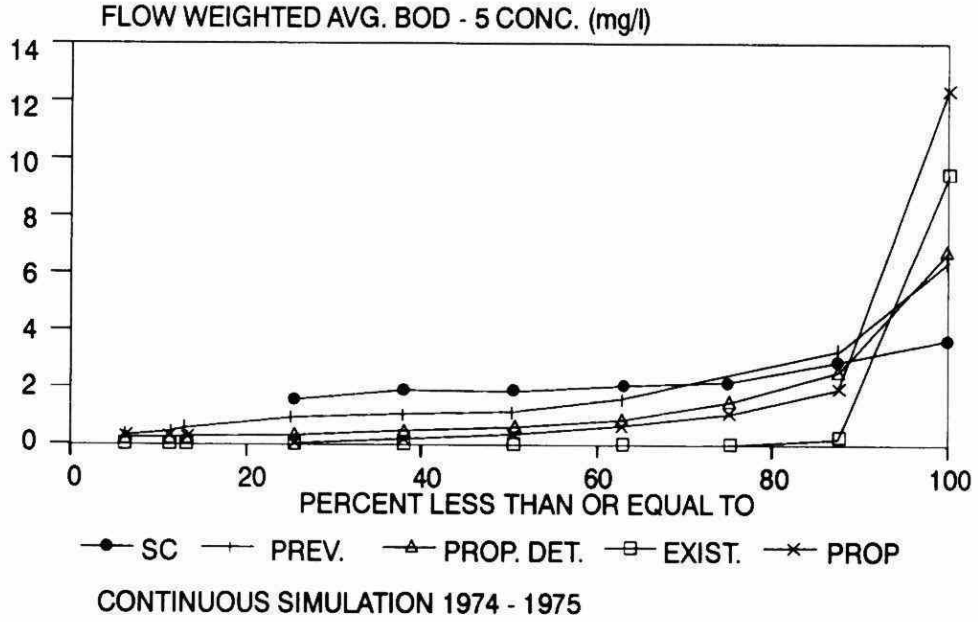


Figure 6.14 BOD-5 Concentration Frequency Distributions for the Five Land-Use Alternatives



6.8 REFERENCES

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CHAPTER 7

Monitoring and Sampling: Requirements for Pollution Control Planning Studies

Dale Henry and Casey Kennedy

7.1 INTRODUCTION

This discussion has been prepared to provide municipal PCP Coordinators and MOE staff with background information on possible monitoring and sampling requirements for Pollution Control Planning studies.

Monitoring and data collection for water quantity and quality is a shared responsibility within the Province of Ontario. Both private and public agencies monitor and collect data for a variety of purposes. Some of these include: environmental compliance requirements, assessment for payment charges, predicting high and low flows for flood and water quality protection, and assessing water quality in the environment. PCP studies incorporate some of the above purposes as well as additional ones. It is the objective of this chapter to elaborate on these purposes by outlining the monitoring and sampling requirements for a PCP study.

To elaborate the requirements of a monitoring and sampling program for a PCP study this discussion has been divided into three sections. The first section examines the issues of a monitoring and sampling program. These issues include:

1. why is a monitoring and sampling program conducted?
2. what should we monitor and sample?
3. where should the monitoring and sampling take place?
4. when should the monitoring and sampling take place?
5. who should do the monitoring and sampling?

The second section of this chapter examines the instrumentation requirements and installation of equipment for the monitoring and sampling of sewers, streams, rivers, nearshore and meteorological events. The third section reviews the needs of an efficient abstraction and data management process. These three sections have to be reviewed in detail before a PCP monitoring and sampling program can prove to be successful.

7.2 ISSUES OF A PCP MONITORING AND SAMPLING PROGRAM

Five issues were outlined in the introduction as issues to be resolved prior to initiating a monitoring and sampling program (why, what, where, when, who). Each of these issues will be described in detail in the following sub-sections.

7.2.1 Why is a monitoring and sampling program conducted?

To successfully conduct a monitoring and sampling program, specific uses for the data must first be identified. The absence of water quantity and quality data for the study area is not enough justification to assume a program is necessary. To justify a program, criteria must be identified that will satisfy specific PCP objectives. These criteria include:

- calibration and validation of specific pollutant models;
- definition of specific cause and effect relationships;
- characterisation of pollutant sources; and
- definition of stochastic/statistical relationships.

Once these criteria are identified the task of describing the specific monitoring and sampling requirements can be carried out.

Pollutant model calibration and validation data requirements are dependent on the type of model that will be used for the PCP study. Basically, there are four types of pollutant models, each having different data requirements. Figure 7.1 presents the data requirements for each type of pollutant model.

Figure 7.1 Monitoring Data Required For Calibrating and ValidatingVarious Pollutant Models

POLLUTANT MODELS				DATA REQUIRED
S1	S2	R1	R2	
X	X	X	X	WATER QUALITY
	X	X	X	WATER QUANTITY
X	X	X	X	RAINFALL
X	X			SNOWFALL
	X	X		WINDSPEED/DIRECTION
	X	X	X	AIR/WATER TEMPS
		X	X	SOLAR INTENSITIES
		X	X	CURRENT DIRECTION
		X	X	VELOCITY
		X	X	DISPERSION
		X	X	TIME OF TRAVEL
			X	STREAM PHYSICAL DATA
		X		NEARSHORE PHYSICAL DATA
X	X			CATCHMENT PHYSICAL DATA

Source Models S1: Urban Washoff
S2: Rural Washoff

Receiver Models R1: Nearshore (Beaches)
R2: River

Pollutant source models (urban and rural) require a minimal database of precipitation, catchment, and water quantity and quality data. Examples of pollutant source models include:

URBAN
Stormwater Management Model (SWMM)
Storage and Treatment Overflow and Runoff Model (STORM)

RURAL
Hydrological Simulation Program Fortran (HSPF)
Chemicals Runoff and Erosion from Agricultural Management Systems (CREAMS)
Guelph Agricultural Model for Erosion and Sedimentation (GAMES)

In most cases pollutant receiver models require as much, if not more, data than source models. The additional data the receiver models may require are: wind speed and direction; air and water temperature; solar intensity; current direction and velocity; dispersion; time of travel; and nearshore data. Examples of pollutant receiver models include:

River Mixing Zone Analysis Program, and
RAND

Defining specific cause and effect relationships is a task that examines a single problem and gathers the information required to solve it, Usually this task has a more variable time-dependent monitoring and sampling program. However, this task usually requires less time to complete than is required for model calibration. An example of a problem-solving task from the St. Catharines PCP is the dye-testing a rock filled breakwall to determine the amount of leakage that will occur at adjacent beaches under various wind conditions. This task took a number of months to complete but only five days of monitoring were carried out.

Characterizing pollutant sources is another task that requires a short duration monitoring and sampling program. Pollutant source investigations are needed in order to identify problem sources so that study emphasis can be focused on them. The characterization of pollutant sources is used as a screening process. An example of this screening process could be collecting grab-and-spot water quality and quantity data for all industrial discharges in a study area and then modifying the program to continuously monitor and sample the

industries that produce significant loadings.

Defining inflow/infiltration to a sewer system provides information on its status and condition. In addition, it indicates the severity of the problem and specifies whether more detailed investigations to pinpoint source reduction areas should be conducted in the future. The monitoring and sampling requirements of this task resemble those needed for the calibration of pollutant source or receiver models.

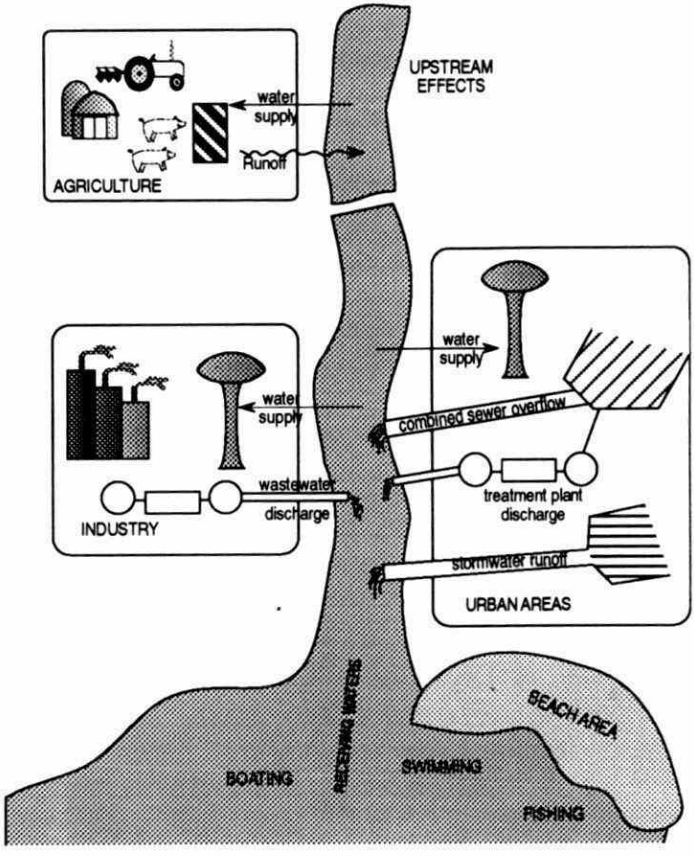
7.2.2 What Should We Monitor and Sample?

The PCP study monitors and samples all major pollution sources and receiving waters within the study area where the data is either limited or non-existent. Pollution sources include: industrial and municipal discharges; urban stormwater and agricultural runoff; CSO's; and upstream (imported) sources. Receiving waters refer to rivers and beaches. Figure 7.2 illustrates pollution sources and receiving waters for a hypothetical PCP study.

Water quantity and quality data from industrial and municipal discharges can generally be established from existing data for conventional pollutants (BOD5, suspended solids, nitrogens and total phosphorus). The MOE publishes an annual operating summary of the industrial and municipal wastewater treatment facilities that discharge directly to the environment. Only a small portion (147) of the province's 12,000 industrial plants are included in the report. The remaining plants discharge into municipal sewers and are treated by water pollution control plants (WPCP). Some of the water pollution control plants (e.g. Regional Municipality of Waterloo) collect data for the major industrial dischargers in order to calculate surcharges.

Water quality data is collected at approximately 740 ambient inland water quality stations (rivers and streams) throughout the province by MOE. Sampling locations have been selected to measure water quality for point source discharges and various non-point source land uses. A core group of water quality parameters (suspended solids, pH, conductivity, chlorides, dissolved oxygen, phosphorus, nitrogen, copper, lead and zinc) is generally collected at each site. On average, six to twelve samples are collected at each site during the course of a year.

Figure 7.2 Pollutant Sources and Receiving Waters in a Hypothetical Study Area



Water quantity data is collected at approximately 385 ambient inland water quantity stations throughout the province by the Water Survey of Canada. Sampling stations for water quantity data have been established to measure streamflow in order to develop flood and low flow curves; this allows for pollutant loads to be calculated. The majority of the stations have 20 to 30 years of continuous data; stations that are located on international rivers have records dating as

far back as the 1860's.

The Atmospheric Environment Service (AES) of Environment Canada collects daily rainfall data at approximately 360 stations throughout Ontario, 85 of which have continuous recording tipping bucket rain gauges which allow for more detailed analysis to be undertaken. AES stations were established to measure precipitation in order to develop statistical relationships for weather prediction, rainfall and runoff. The majority of stations have over 20 years of continuous data.

7.2.3 Where Should the Monitoring and Sampling Take Place?

Monitoring and sampling for a PCP study occurs primarily in three locations: in sewer; in stream; and nearshore areas. These locations vary significantly in the data that is collected and the environment in which the monitoring or sampling is conducted. In addition, the selection of each station is dependent upon the required task or purpose for which that station was established. The following text illustrates the difference between the types of stations and the level of effort that is required in the selection of sites for model calibration and specific site requirements.

The process for the selection of monitoring and sampling sites for the model calibration of stormwater runoff and/or CSOs within a municipality is a multi-overlay mapping process. This process assumes that catchments can be selected to represent the majority of the area in the municipality. The first step is to provide a base map of the municipality at a suitable scale so that small sewer catchments will be well-defined. The second step is to develop an overlay map displaying storm and combined sewer catchments. Downstream combined sewer areas that receive input from upstream stormwater areas or downstream storm sewer areas should be outlined and eliminated from any further consideration. The third step is to prepare an overlay that depicts the various land use classifications (eg residential, commercial, industrial, open etc). Any land use classification that comprises less than 5% of the total area of the municipality should be removed from any further consideration. Step four is to select a catchment with a uniform land use classification by overlaying the storm and combined sewer catchment map with the

land use classification map. Selection of two to three catchments per land use classification (with greater than 5% of the total area of the municipality) should be made at that point. Step five is to conduct a detailed investigation of the catchment areas to ensure correct sewer configuration and land use classification. This allows for the most representative catchment area per land use classification to be selected. Step six is to conduct a detailed investigation of the catchment sites to ensure safety (no toxic gases, no structural defects), good regular sewer flow (avoid sites with debris plugging, upstream junction sewers, backwater conditions), and ease of installation and maintenance of equipment (ensure that monitoring and sampling equipment can be situated on-site). If the site is unsafe, has super critical flow with surface waves or is unable to contain instrumentation then step six should be repeated for the next representative catchment area.

The selection process for monitoring and sampling sites for model calibration of a river (stream) system is a river reach discretisation process. The first step is to identify the significant sources of water quantity and/or quality entering the river system throughout the study area. Significant sources should include industrial and municipal discharges, storm and combined sewer outfall flows, streams and tributaries. The second step is to segment the river into reaches that are uniform in regard to: velocity, cross-sectional areas, flow and a complete mix of significant pollutant sources at the downstream end of the reach. The third step is to carry out a detailed investigation of the monitoring and sampling site(s) to ensure safety (accessibility), good regular flow (avoid sites with eddies and backwater), uniform channel dimensions upstream and downstream, and a stable river bed. If the site does not meet the conditions established in steps one to three then the process will have to be repeated for another site.

The selection process for monitoring and sampling sites for the calibration of a nearshore (beach) model is separated into two components. The first component examines the requirements for water quality data and the second component looks at the placement of field instrumentation (e.g. current direction/speed meters). For water quality stations (beach sites) the sites must be permanently fixed and should be located at intervals of 30 to 50 metres transversing the beach. Sampling is conducted in the water at a depth of one metre and at the beaches where very shallow water exists; the

samples should be collected as far off shore as possible yet still remain within the swimming area. Stations should not be located where they are directly impacted by a point source (if this is not possible then additional stations will be required).

Current direction/speed instrumentation is used to provide input into the nearshore models (e.g. RAND). The instrumentation should be placed in representative areas that are suitable to the model selected. Positioning of the instruments can be completed as illustrated in Figure 7.3. Instrumentation should be located away from major boating and shipping channels.

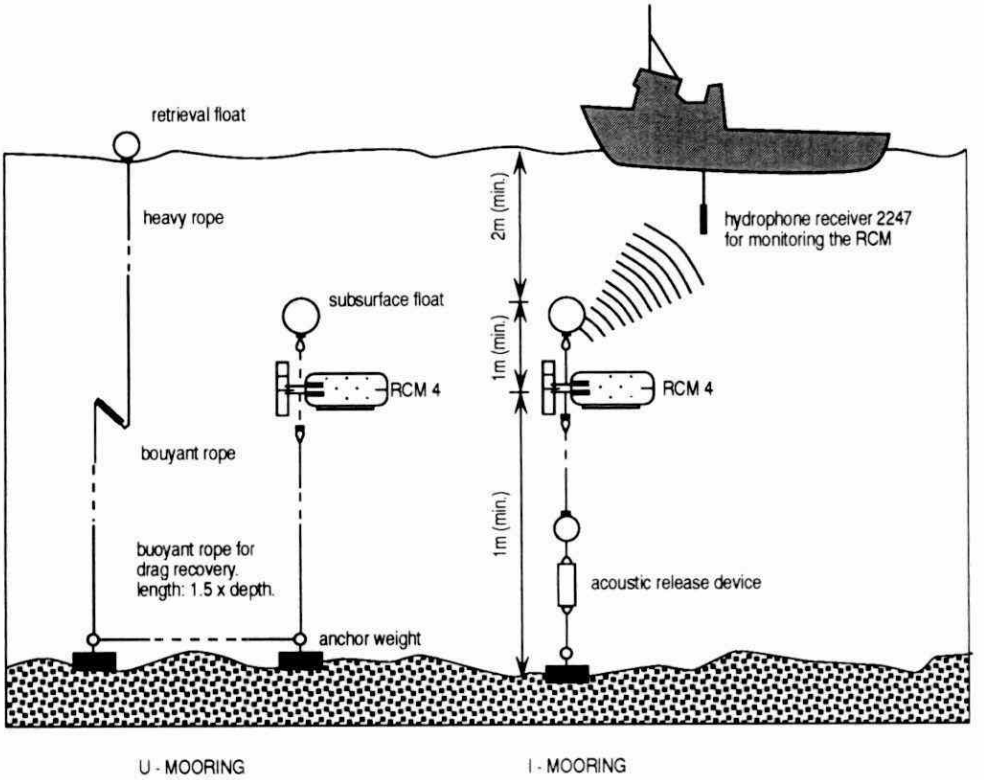
7.2.4 When should the monitoring and sampling take place?

As indicated earlier in section 7.2.1 the intensity of the monitoring and sampling program for a PCP study can vary. The program can range from collecting samples on an annual basis to monitoring the sewer flow to a minute or less. The PCP study generally collects data within four time ranges; daily, one to four hours, continuously, and periodically. Typically, annual and seasonal data is collected by agencies outside the PCP study.

Daily monitoring and sampling data is usually collected for the development of simple models of steady state or slow changing conditions (e.g. Beale Ratio Estimator). Examples of steady state processes that require only simple models include industrial and municipal discharges and large rivers. It should be noted that discharges may vary with regard to water quality on a daily basis (e.g. WPCP effluent), therefore composite samples should be collected at these sites.

Monitoring and sampling programs that collect data at one to four hour intervals are designated intensive surveys. This type of survey is usually carried out over a short duration (2 to 4 days). Examples of this type of survey would include waste assimilation capacity studies (to determine the total oxygen demand (TOD) of a municipal discharger) as well as cause and effect relationships.

Figure 7.3 Positioning of Instrumentation



Continuous or nearly continuous monitoring and sampling programs collect data to develop and calibrate the sophisticated pollutant models. Monitoring and sample collection are carried out at very small increments. Water quantity from CSOs, stormwater and small tributaries during wet weather are usually collected at a one to five minute interval. Water quality data during wet weather is usually collected at a ten to twenty minute interval. Current direction/speed data is typically collected every twenty minutes.

Periodic monitoring and sampling programs are conducted to confirm an identified source. The program would include spot flow measurements and grab samples for water quality. Examples of this type of program would include storm sewer outfalls and small tributaries.

7.2.5 Who should do the monitoring and sampling?

The monitoring and sampling for a PCP study can be conducted by an individual agency or a combination of agencies. Agencies that carry out this type of work include: municipalities, consultants, MOE, Environment Canada and Provincial Health Units.

If a municipality or consultant undertakes a monitoring and sampling program, contract staff are usually hired to fulfil the manpower requirements. The various levels of staff needed to carry out this type of program are: a field supervisor, a field technician and a number of samplers. The main responsibilities of the field supervisor include:

- assurance of safety procedures;
- selection of monitoring and sampling sites;
- scheduling of field activities; and
- assurance of data validity.

The main responsibilities of the technician are:

- the installation, maintenance and downloading of the data from the monitoring instruments;

- the development of sampling protocol and submission of samples to their respective laboratories for analysis; and
- the development of rating curves for both sewer and stream profiles.

The main responsibilities of the samplers include:

- collection of water quality samples; and
- assisting in obtaining stream and sewer flow measurements for the development of rating curves.

The hiring of contract staff would be carried out by the personnel department of the agency conducting the PCP study (usually the municipality). This process would include writing and approving the job descriptions, classifications and salary ranges, as well as advertising the positions, interviewing and final candidate selection. It usually takes 1.5 to 2.5 months for this process to take place within a municipality. In general, consulting firms have a much quicker hiring practice.

The timing of staff hiring is an important factor for consideration. Most PCP studies are initiated during the summer periods (April to October). Thus hiring procedures should commence in early January. The field supervisor should be the first hired. This allows the supervisor to develop a framework for the field program before other staff come on-line. The technician should be hired approximately two weeks after the supervisor and two weeks prior to the samplers. This allows the technician time to install all of the instrumentation. It should be noted that if any instrumentation has to be ordered this process could take up to ten to twelve weeks to complete.

During the first week of employment (when all staff are on-line) safety courses must be provided in accordance with the Provincial Safety Act. These courses may include all of any of the following: confined space entry, proper sampling hygiene, safe sampling protocol and safety signalling for traffic obstructions. In addition to these courses, training sessions would also be provided for sampling methods, use of instrumentation and equipment, and general background information regarding the program.

Environment Canada and the MOE may participate in the

monitoring and sampling program if they are carrying out additional field work in the study area. Some of the work these agencies carry out include: toxic, river assimilation and beach surveys.

Health Units routinely sample beach areas during the summer periods to determine if any health risks exist and may wish to participate in the field program.

In all sampling programs analysis of the sample is a necessity. The analysis must be carried out by an agency that follows standard methods of testing and is reliable in quality control and assurance. The laboratory where the analyses will take place must be capable of handling the following:

- type of analysis (parameters/scans)
- number of samples (large volume over a short duration)
- days of analysis (can samples be submitted on weekends and holidays?)

In some cases a number of laboratories may be needed to ensure complete sample analysis.

7.3 INSTRUMENTATION REQUIREMENTS

Instrumentation requirements for a PCP monitoring and sampling program can be divided into four areas of study. These areas include:

1. in-sewer quantity and quality,
2. in-stream (nearshore monitoring) quantity and quality,
3. meteorological, and
4. special studies, such as time of travel, and nearshore dispersion.

Each of these areas requires unique instrumentation which will be discussed in detail below.

7.3.1 In-Sewer Instrumentation

In-sewer instrumentation consists of flow monitoring and water quality sampling. Flow monitoring is achieved by measuring the depth (level) of water in the sewer and converting it into flow through the use of a rating curve. A rating curve is a relationship derived by plotting depth of water against spot discharge measurements. Another method of in-sewer monitoring is to measure simultaneously the depth of water and the velocity which allows flow to be calculated.

At present there are five different types of level sensors employed in this type of work: dipping probes, floats, bubblers, pressure transducers and ultrasonic. The dipping probe is an electromagnetic probe that constantly dips into the flow of the water. The probe measures the difference in conductivity between air and a liquid. The level is a measure of the height of the probe as it moves in and out of the liquid. The float system comprises a buoy or float that remains stationary on the surface of the flowing water. Thus the level is recorded as the float moves up and down with the water level. The bubbler system measures the pressure to force a gas (air) through a column of liquid. The pressure is then converted into a liquid level. The pressure transducer is based on the pressure difference principle which takes the normal atmospheric pressure and compares it to the submerged pressure of the liquid column. The pressure difference is then converted to a liquid level. The ultrasonic system measures the time it takes an emitted ultrasonic wave to travel to the surface of the water and return back to the probe. The time taken can then be converted into a liquid level.

In-sewer water quality sampling can be simplified through the use of an automatic wastewater sampler or samples can be collected manually (grab samples). Grab samples are usually taken at manholes (from the surface) or at outfalls with the use of sample buckets, rope or reach poles. Grab sampling is the preferred method of collecting samples for bacteriological analysis.

Automatic samplers are available from a number of suppliers. There are a number of different types of automatic samplers each with varying features. Key questions in deciding on the acquisition of an automatic sampler are:

1. are discrete or composite samples required? (a composite sample is a series of discrete samples collected in one container)
2. how many samples are required and of what volume? (a receiving laboratory should be contacted for sampling submission procedures)
3. can samples be flow weighted?
4. can sample lines be purged?
5. how far or high can the sampler pump a sample?
6. what is the draw time per sample?
7. can samples be refrigerated?
8. what type of bottles and tubing can be used with the sampler (glass, plastic, tygon tubing)?

Representative flow is required in order to properly carry out in-sewer flow monitoring and water quality sampling. An ideal location would include the following characteristics:

- regular flow during both dry and wet weather;
- no influence from upstream junctions;
- no backwater conditions;
- water depth adequate for sampling; and
- no surcharging during wet weather.

If these conditions can be found then good flow measurements and representative samples will be collected.

7.3.2 In-stream Instrumentation

In-stream monitoring instrumentation resembles that of in-sewer monitoring in that they both consist of flow monitoring and water quality sampling. Generally the same instrumentation that is used for in-sewer monitoring can be used for in-stream monitoring. The float level sensor is the flow monitoring instrument that is used in most in-stream monitoring programs. This type of instrument is appropriate for mid to long term data collection (up to five years). For shorter duration data collection (such as required for PCP studies), pressure transducers or ultrasonic sensors are used because of their ease of installation. These level sensors also have a far greater degree of portability. In-stream sampling follows similar procedures as set out for in-sewer sampling.

Housing of instrumentation used for in-stream monitoring and sampling programs should be given a considerable amount of thought. Key questions that should be answered are:

1. should the housing be portable and re-usable?
2. where should the housing be located (high and dry)?
3. should the housing have a power supply or telephone connections?
4. should the housing be heated?
5. what size should the housing be (room for equipment only)?
6. how can housing be made vandal proof?

Nearshore monitoring instrumentation consists of current direction/speed meters and current drogues. Current drogues are released within the areas of concern and monitored from shore using infrared distance recorders and theodolites (angle measurements). With this information time varied plots of the drogues can be prepared. Current direction/speed meters are situated in areas that will provide the data for nearshore model calibration. These meters can be located underneath the surface of the water thereby not causing any disturbance to boating activities (see Figure 7.3). Servicing these meters requires use of boats, therefore staff should be familiar with the operation of boats.

7.3.3 Meteorological Instrumentation

Meteorological instrumentation includes rainfall and temperature recorders. Rain gauges can be classified into two categories: manual totalizer and continuous recording gauges. The totalizer measures the total amount of rainfall (in millimetres - mm - or in inches - in.) that has accumulated over a period of time (usually a twenty-four hour period). The totalizer has to be manually read, recorded and reset.

The tipping bucket rain gauge is the most commonly used continuous recording rain gauge. The gauge usually records the rainfall in increments of 0.2 mm (0.01 in.); this is determined by the calibration of the tipping bucket. The rain is funnelled into the

chamber containing the tipping buckets, and when the amount of rainfall is equal to the calibration of the bucket (usually 0.2 mm), it tips sending a message to a time based recorder.

Temperature recorders also have two categories maximum/minimum thermometers and continuous recording thermometers. The maximum/minimum thermometer measures the maximum and minimum temperatures that occur over a specified time period (usually one day). The thermometer has to be read, recorded and reset manually. The continuous recording thermometer measures and records temperature over a discrete long term duration (weeks).

7.3.4 Special Instrumentation

Special instrumentation may be required for various aspects of PCP studies. The St. Catharines Area Pollution Control Plan (SCAPCP) required the use of bacterial die-off chambers. The chambers were used to determine the decay rate of bacterial organisms in various types of receiving waters (i.e. cold, low nutrient; and warm, high nutrient waters). Instrumentation staff must be trained in the safe and proper use of the equipment.

7.4 MONITORING AND SAMPLING DATA MANAGEMENT

There are two key areas that need to be examined for data management in a PCP study:

- producing manageable data efficiently; and
- ensuring that the data is reliable.

In all studies that involve the collection of data, efficient management is important as it will save on the cost of data abstraction, storage and transposing. Abstraction is the removal of data from an instrument recorder and producing the data in a usable format (eg. computer data files). Data storage refers to the media in which the data resides

(eg. hard copy, hard disk, floppy diskette). Data transposing denotes a change in the format of the data (eg. converting raw data into a data input file for a computer model).

The preferred method for data abstraction is the one that minimizes the amount of manual manipulation needed to process the data. The following is a conceptual process:

1. data is logged at the source magnetically to a micro-chip (datalogger);
2. data is retrieved periodically from the datalogger by an interrogator;
3. data is transferred from the interrogator to the main computer system;
4. data is formatted so that it will be compatible for other uses (or can be converted by existing software).

Once the data has been processed it should be compatible for use in models, statistical regressions and analysis, and to develop cause and effect relationships. Requirements of a preferred data abstraction system include: data loggers, interrogators, computer conversion software and personnel with programming skills.

Data abstraction, using the process outlined above, can be carried out in the following areas: in-stream and in-sewer level and velocity meters, precipitation and temperature gauges, current direction/speed meters, and some water quality parameters (dissolved oxygen, pH, conductivity and temperature).

Once all of the data has been abstracted and stored it has to be transposed into a workable format. Transposing the data from raw files involves segmenting the data into areas of interest. Sewer flow that has been collected at a five minute interval for a six month period represents approximately 53,000 pieces of information. This information could be transposed into two different formats. One format would be to separate the data into wet and dry weather files. The other format would break down the data into daily or event records. In both cases the data has become easier to sort through. It should be noted that no data should ever be discarded as it might prove useful in future analysis. Data that is not relevant to the study should be removed, catalogued and stored elsewhere.

Data validation is the final stage in the data management process. Errors in this process could occur at all stages including: the source instrument, datalogger, interrogator, computer, software and all of the connections between each piece of equipment. All data should be plotted and examined for outliers and anomalies that cannot be explained. The question that has to be answered during this stage is "can the data be reproduced again under the same conditions?"

7.5 SUMMARY

The key to developing a sound monitoring and sampling program for a PCP study is in answering the following questions:

1. why is a monitoring and sampling program conducted?
2. what should we monitor and sample?
3. where should the monitoring and sampling take place?
4. when should the monitoring and sampling take place?
5. who should do the monitoring and sampling?

A brief overview of the factors involved in answering these questions is given below.

A monitoring and sampling program is conducted if it is necessary to collect additional information in order to carry out the following tasks:

- calibration and validation of specific pollutant models;
- definition of specific cause and effect relationships;
- characterization of pollutant sources; and
- definition of stochastic/statistical relationships.

Each of these tasks requires different types of data sets. In most cases a database may be available from existing agency programs (Water Survey of Canada, Provincial Water Quality Monitoring Network, etc.). Where the data is limited or non-existent a monitoring and sampling program should be established so that the required data can be obtained.

Monitoring and sampling is conducted primarily in three locations: in-sewer, in stream, and nearshore (beach) areas. The data collected varies significantly based on the location. The selection of monitoring and sampling sites requires different levels of effort depending upon location (these are outlined in Section 7.2.3).

The monitoring and sampling program generally collects data in four different frequencies: daily, one to four hours, continuously, and periodically. The time frame selected is based upon the site location and the amount of data that is needed to fulfil the requirements of the model for which the data is being collected.

The monitoring and sampling program is carried out by an individual agency or a combination of agencies such as: municipalities, consultants, MOE, Environment Canada and the Provincial Health Unit. When the program is carried out by a municipality or a consultant, contract staff are usually hired to fulfil the manpower requirements. Three levels of staff are required to carry out the program: field supervisor, field technician and samplers. The process of hiring staff is the responsibility of the agency conducting the PCP study.

Instrumentation requirements depend upon the location that is being monitored and sampled and the type of data that has to be collected. There are basically four areas that a monitoring and sampling program can be divided into: in-sewer quantity and quality, in-stream quantity and quality, meteorological, and special studies. Each of these areas requires unique instrumentation (outlined in Section 7.3).

Data management for a monitoring and sampling program should produce manageable data efficiently and ensure that the data is reliable. The data should be processed so that it is compatible for use in models, statistical regressions and analyses, and developing cause and effect relationships. In order to validate the data it should be plotted and examined for outliers and anomalies that cannot be explained. If the data can be reproduced under the same conditions then it is accepted as valid.

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CHAPTER 8

Finding Middle Ground: Developing the Best Solution to Complex Environmental Problems

Sally Leppard

8.1 INTRODUCTION

There is no shortage of disputes. There are disputes between husband and wife, between siblings, between friends, between individual and firm, between firm and firm, between developer and environmentalists, between regions within a nation, between a region or city or state and the nation, between nation and nation - and perhaps in the far future (who knows?) between planet and planet.

There are many established ways for settling disputes: traditions, regulations, courts, markets (through the laws of supply and demand) and negotiations. As conditions change, so too must the rules. But how should the authorities change these rules? Frequently by the processes of bargaining and negotiation. Citizen participation and public involvement are the first steps to be taken, at the outset of any project, to ensure that any potential dispute is anticipated, and steps taken to adapt the project to human and social concerns. A better project will usually result.

The history of citizen involvement in Ontario is a relatively new field as we know it, going back only a decade or so. However, disputes have been with us for ever, and citizen participation is very important today.

There is an art in citizen participation, leading to negotiated planning. There is also a science, i.e. systematic analysis for problem

solving. The art side of the ledger is slippery: it includes interpersonal skills, the ability to convince and be convinced, the ability to employ a basketful of bargaining ploys and the wisdom to know when and how to use them. The art of negotiation is well documented, but the science of negotiation on the other hand is not well developed, and not much is available to practitioners. This paper will focus largely on the *art side* of the process.

8.2 THE GROWTH OF CITIZEN PARTICIPATION

At the beginnings of citizen participation, or the formation of the 'grass roots environmental movement' in Ontario there appeared, in the early 1970s, a poster of a glass of Don River water, with the caption "Would you drink a glass of Don River water?".

Books entitled *The Power to Make It Happen, Rules for Radicals* and *Up Against City Hall* began to appear. The doors of Ontario's cherished offices began to be pried open by curious, and often hostile citizens, demanding copies of internal policies and correspondence. Sensitivities were challenged, credibility threatened, no one knew how far to go or how much to give.

Citizen participation in Ontario is not new. Since the Planning Act came into force, citizens have been called to public meetings to have projects explained to them. The Town meeting was usually the only way to involve the public, and the process was usually adversarial and hostile.

Burgeoning development across Ontario in the early 1960s, and the resulting substantial population growth, has left behind its costs and conflicts. Land use planning and water quality issues that were once simply resolved now cut across every facet of our society - bringing with them differences of opinion - frequently on a macro scale. Bitter disputes over land, water and natural resource management and development dominate the media. Environmental concerns top Ontario's list of priorities. The field of public consultation has evolved as one way of making tough decisions easier.

Resolution of these disputes is normally through quasi-judicial and administrative tribunals such as the Ontario Municipal Board Planning, the Environmental Assessment Board (environmental

quality), the Consolidated Hearings Board (planning, environment) or the courts.

Costs for these hearings can reach hundreds of thousands of dollars. Moreover, the adjudicated results are not always the most technically sound and cost effective, nor necessarily in the best public interest.

Planners and policy makers, recognizing the impact of public intervention, began to incorporate citizen participation and consultation into their planning processes - usually at the end of each stage of a process, and usually by convening public meetings. The results were usually the same - particularly in a controversial planning matter such as a landfill site, gravel pit or water control project, such as a dam.

Because of the controversial nature of the environmental control project, we began to see the evolution of the Public Advisory Committee (PAC). This was usually a group of citizens who worked with the study team and their constituent groups to develop a better plan. The PAC was supported by the proponent who developed public relations (PR) material such as glossy brochures praising and justifying the project. PR firms were hired to steer the project through the process. The public reacted using words such as 'whitewash' and 'window dressing'. A hardening of positions on either side led to costly dispute resolution mechanisms usually through the courts or quasi-judicial tribunals, so policy makers began to look at more effective ways of including the public.

The *not in my back yard* (NIMBY) phrase was coined.

8.3 THE 'NIMBY' SYNDROME

Before describing how to generate energy, creative ideas and enthusiasm but most importantly, "APPROVED PROJECTS" from the "Not in My Back Yard Syndrome", a little story, the "Parable of the Clock and the Whistle" will set the backdrop.

In the window of a clock-maker's shop in a small, one factory, northern Ontario town, the owner placed his prized clock for all to see.

The whistle of the local factory sounded each morning to start the working day for the majority of the townsfolk.

The clock-maker noticed that at the beginning of each day, the same man stopped and admired the prized clock, compared the time with that on his time piece and left.

Many years later, the clock-maker's curiosity compelled him to ask the man why he had such a consuming interest in his clock. It turned out that the man was responsible for blowing the factory's whistle each morning. He stopped to set his watch to match the time of the clock-maker's clock to make sure he had exactly the right time each day.

"Very interesting", commented the clock-maker. "That old clock looks impressive, but it doesn't keep good time. I always wait 'til the whistle blows and then set my clock to match it."

The moral of this story is that the wrong decision, based on a faulty assumption and poor communications, can have a widespread, and sometimes devastating impact.

8.3.1 Resolving conflicting values

Conflicting values usually are the root cause of environmental disputes frequently called the NIMBY syndrome.

But conflicts and disputes form part of our daily lives. Some of us have skills and find negotiation easy; others avoid conflict resolution at all cost - we shut out problems.

The symptoms of disputes follow a consistent pattern - one or more of the parties feel they've been exploited; positions harden; the atmosphere becomes emotional, even hysterical; the media focuses on the argument or position.

The proponent can spend thousands of dollars on hearings and lawyers to prove that his solution is just. Big and small organizations, Godzilla and Bambi, fight it out. This is an adversarial process of resolving disputes which tests our professional mettle. There's no co-operation.

Far more creative ways are needed to address co-operative problem solving, e.g. in South Simcoe the community's motto is:

"we all create waste, we're part of the problem and part of the solution".

But certain criteria must exist for co-operative problem solving:

- a credible spokesperson who knows the bottom line,
- examples of such problem solving - the waste management master plan process (Wellington/Guelph) and Remedial Action Plan (RAP) process (Hamilton Harbour) - are provided later, in sections 8.4 and 8.5 respectively.

8.3.2 A hypothetical case

Let us consider some examples of private projects where the NIMBY syndrome develops, and why the syndrome develops.

This is a hypothetical gravel pit case which many may recognize: in rural southern Ontario lies a small peaceful agricultural community. Ex-urbanites from the City of Toronto have begun to settle in the area, and live peacefully on their hobby farms. The landscape is littered with worked out pits, as many as 50 within the geographic municipal boundaries. Many other pits are operating. Public perception of the industry is at an all time low, since the demand for product has caused hours of operation to extend from 6:00 in the morning to 9:00 at night during the summer.

John Doe, a stockbroker from Bay Street, has managed to purchase a place that is not affected by the industry. One day he is told through the mail that a pit will be planned for the parcel next door and he has 30 days to respond or request a hearing (he was asleep when the zoning amendment went through local council).

Panic sets in, and all of a sudden, the environmental conditions of his and adjacent property become paramount. He discovers that his wetland is "provincially significant" and sights a rare warbler. From observing the industry in other areas of his Township, he notices the enormous disruption caused to the neighbours and roads. Immediately, his reaction is adversarial, and his decision is made to fight the proposal until it or he dies. Neighbours are canvassed, provincial lobby groups are approached, lawyers are

retained and the fight is on.

The proponent in the proposal cites the need for the undertaking, that the Province is running short of gravel, and that the gravel that just happens to underlie his area is the only place where they can extract it economically to supply the market. The proponent becomes defensive, hires the best engineers, landscape architects, petitions the provincial government agencies to support his case, and lobbies council. The proponent begins to prepare mitigation plans and may approach the residents, through his lawyer. Citizens who support the proposal boycott John Doe's kids at school, opponents have bake sales to raise money to fight the case.

An important impasse has been created, largely because the residents don't accept the fact that there is need for the proposal. All they have to do is look around the township to see the legacy left by the industry.

For the proponent, going into meetings of angry, upset residents is not a desirable task, particularly since the proponent has no intention of backing off. And the residents are only one stakeholder in the entire process; there are many others - the agencies, the politicians, and of course, all the lawyers.

It is not appropriate to tell Mr. Doe and his buddies "we're not disrupting this wetland because it is an important natural resource, so we're mining around it". They know that there is no mineable aggregate in that wetland, and that development of a Class 1 provincially significant wetland resource is not allowed.

The proponent must be advised at the outset that notification through the mail to established landowners is not an appropriate way of doing things. Using words like "*mitigation of environmental damage*" will not succeed either. To residents, these words are just words - because the proponent won't be around later to rectify the problem that may be created by the open pit mine. The proponent does not have to live next to it either.

8.3.3 A wiser strategy

A better way of doing things is first, announce the fact that the proponent wants to mine that area. From there, the plan must become an open book. Discussions with all parties, together in the same room, develops and instills trust. It's the private, in camera meetings with politicians and agencies that disturb people so much.

Get the concerns on the table - what are they really? Noise, dust, compensation, traffic, disruption of the water table. The proponent should work together with these people when developing the site plan. Not in a public meeting, but around the table, with sleeves rolled up, from the beginning.

The proponent should not deny that a proposal is disruptive if it is. Creative environmental design can mitigate the impact. And surely the proponent will commit resources in the long term to ensure that the residents' water wells will not be affected.

And if they are, the water will be restored. If property values are impacted, then compensation packages can be developed to relieve the burden.

Such a plan put before the Ontario Municipal Board will be a better one, both for the citizens and their environment, and takes less time to get approval, thereby saving residents and the proponent many thousands of dollars. NIMBY, if seen to be a positive contribution to the planning process, can work well.

8.4 THE CONTENTIOUS ISSUE OF WASTE MANAGEMENT

Waste planning is probably the worst case scenario in public consultation. Planning for waste management in Ontario has become a major public issue. Because of the sensitivity of Ontario's eco-system, environmental protection has become the number one priority for most citizens. In Ontario, public awareness in these issues is at an all time high.

This shift of public attitude toward environmentally sound waste management solutions, is reflected through a planning and legislative framework, which, in the author's view, is world class. The process incorporates the following:

1. a statement of current conditions and definitions of the problem;

2. review of all feasible waste management options;

3. selection of a waste management system which is environmentally, economically, socially, and technologically acceptable;

4. development of a waste management master plan;

5. environmental assessment branch review, and pre-submission consultation with all interested parties;

6. plan approval, change or rejection before a public hearing board; and

7. implementation.

With these checks and balances, and citizen participation throughout, the process provides for intense scrutiny, innovation, public education, and an openness which should assure that the best plan is developed.

8.4.1 An example of delayed citizen involvement - Guelph and Wellington County

Wellington County and the City of Guelph are located in the heartland of south central Ontario. The city, with a population in the 80,000 range, supports Canada's foremost agricultural and veterinary university. It has its own local government - the Guelph City Council. The county, surrounding the City of Guelph, comprises 21 individual municipal jurisdictions, each of which participates in the Wellington County government. The primary land use in the county is rural agriculture.

Traditionally, the city and the county have formed alliances on many issues, such as transportation, public health issues and planning - and they have demonstrated a long standing relationship of co-operation.

Each individual municipality, including the City of Guelph, has control over waste generated within its boundaries. Until very recently, each individual municipality collected and disposed of its own garbage, normally through dumping and/or burning.

In 1982, the county fathers recognized that rationalizing the *ad hoc*, lower tier municipal method of waste disposal may have distinct benefits - if the county were to collectively participate in the development and management of an energy-from-waste (EFW)

incinerator. The City of Guelph's co-operation was sought in this venture, since the county alone did not produce enough garbage to support an EFW. Of the total 177,000 tonnes of wastes generated each year within the city/county boundaries - only 35,000 tonnes is produced in the county. As well, the county was aware of the difficulties of locating new landfill facilities, and expected to benefit economically and environmentally by sending all its waste to the city. The city, which was running out of landfill space, also expected to benefit from participating in a joint plan, because an incinerator would reduce its dependence on landfill.

In 1983, the MOE developed a funding program for municipalities to jointly plan for the future management of their waste. The waste management master plan process funded 50% of the total study costs. The requirement however, was that municipalities review alternate technologies (not only landfill or energy-from-waste) and develop an environmentally sound and comprehensive waste management system, which would provide for the area's waste disposal needs for at least 20 years.

The City of Guelph and the County of Wellington collectively took advantage of this funding base, formed a joint waste management steering committee, representing both the city and the county, and began to study the problem of waste management.

The steering committee decided to follow the terms of reference for the study as provided by the MOE.

Stage 1: Review the existing waste disposal situation in Wellington County; project volumes of wastes to be managed over the 20-40 year planning period; and identify candidate areas for landfill through constraint mapping (desk-top review of existing reports). The report identified areas to be avoided for locating landfills, such as wetlands.

Stage 2: Review alternative waste management options, such as recycling, energy-from-waste. Further screen candidate landfill areas from an agricultural perspective. Identify candidate sub-areas.

Stage 2B: Select candidate site(s) for landfill and energy-from-waste facilities. Recommend recycling for marketable commodities. Develop the preferred option for a waste management system.

Stage 3: Complete master plan document. The master plan, containing a description of the preferred system and locations for

system components could either go before the Provincial Environmental Assessment Branch for Review as an "Undertaking" in its entirety, or individual components may go forward for approval, using the master plan as a background document for the review of alternatives.

While it was appreciated that public involvement in the development of the master plan was an important element of the study, the study consultants thought it advisable in the first two stages to hold public meetings after each stage had been drafted. During the first three years of the study (1983-1986) very little public interest was demonstrated in the study's progress - largely because of limited outreach efforts.

In January 1986, the steering committee announced candidate sites for landfill, - 10 or so in the northern most part of the county, and possible locations for energy-from-waste facilities within the city. Immediately, opposition to the plan began to form. Every fundamental premise inherent in the plan was challenged and it became clear that the plan had been developed in the absence of community goals and aspirations. The steering committee and study consultants naturally responded defensively to the criticism, and over a two year period, neighbourhood groups and the steering committee communicated their views through the news media. Direct contact was confrontational by nature, highly charged and largely unproductive.

The steering committee and its technical advisors had been meeting 'in camera' since the study began. As well, technical advisors had become voting members on the steering committee, which was considered by some citizens to be inappropriate. Because of these factors and the extent of the criticism, a substantial amount of mistrust between the public and the decision-makers began to develop.

It became clear that there was no formal vehicle for public input, no method for two-way dialogue, and a lack of staff resources to handle public information inquiries. Certainly, the approach turned away from consensus-building and community based planning concepts toward an adversarial approach to waste planning.

In addition to the developing impasse between steering committee and affected groups, over the suitability of several of the candidate landfill sites, the debate intensified since the city was party to the landfill search, but created most of the waste. Community reaction in the county to the landfill proposals was adversarial.

Citizens within the City of Guelph also became anxious about the human and environmental health effects of the proposed energy-from-waste facility, and insisted that the plan contain maximum resource recovery before either incineration or landfill.

Data contributed to the study by concerned citizens' organizations and agencies identified several problems with some of the candidate sites. For example, in one area, wetlands were evaluated and demonstrated to be Class I provincially significant wetland resources. In another area, a candidate site was within a few kilometres of the village's new water supply.

From the perspective of the steering committee, the purpose of the candidate site review was to select the 'best' sites at the desk-top level, and then conduct detailed field assessments of each proposed area, prior to determining the preferred site or sites.

From the perspective of some concerned citizens, the study should have been conducted in a much more thorough fashion from the outset, included fundamentally different objectives, and excluded the City of Guelph from the county's planning process. Others recognized the need to incorporate landfill in the plan, but challenged the site selection process.

To add fuel to the fire, the county and the city jointly do not have the mandate to implement the plan. What was once an exercise in developing a desk-top planning model for waste management, became an action plan for implementation - with no clear authority as to who could manage the waste. As pointed out earlier, each municipality has the individual authority to dispose of wastes, including the City of Guelph. However, a new, safe waste management system could easily be beyond the economic reach of individual municipalities. What was required was authority granted from the provincial government to permit the county and the city to jointly manage and dispose of wastes. The granting of this authority has been pending for over a year. In June, 1987, an independent public consultation and conflict resolution expert was retained by the steering committee to develop a strategy to involve the public in the development of the waste management master plan.

Each municipality and interest group was interviewed over a two-month period. Participants were asked their opinion about the process and content of the plan. Suggestions for their future involvement were solicited, along with an understanding of what was required (on their part) in order to effectively participate.

The consultant documented the concerns of the participants and developed a program which was based on the assumption that participants would:

"agree, at the outset, to develop areas of common ground and narrow points of difference".

The report pointed out that without this commitment from all parties, the proposals would not be achievable.

The report included the following elements:

- a set of basic principles to be included in the waste management master plan for Wellington county and the city of Guelph;
- observations regarding roles and responsibilities of the key actors;
- a public involvement and co-ordination strategy, including a public awareness, education and involvement program.

This strategy included:

- developing an awareness of the existing status of the plan in the minds of the general public and 'stakeholders' including government agencies;
- formalizing the citizen participation process through the establishment of a public advisory committee - who would act as advisors to the steering committee;
- developing newsletters and bulletins on a regular basis to explain progress; and
- arranging special workshops for municipal councillors and the general public on the final reports.

In developing this report, the consultant negotiated its contents with the most-affected groups - the steering committee and the concerned citizens organizations around candidate sites. By October, the report had received public input and achieved consensus by all parties concerned.

As with all such negotiated frameworks, time is required to implement change. All parties are still using the news media to communicate their views to the general public, until such time as the new process is established.

Figure 8.1 Procedures to resolve conflict

RESOLVING CONFLICT

Determine interested parties

Contact, talk, interview,covering:
- history
- expectation
- process questions
- content questions
- ideas on resolving dispute
- commitment to negotiate and resolve if conditions met

Develop first draft report on
- process issues
- content issues
- mechanisms to resolve process questions
- commitment necessary by parties

Allow plenty of time for review

Meet with vested interests

Negotiate one-on-one

Develop final report

Meeting of parties - consensus (Process)

Establish new process

The challenge that now lies before the steering committee, participating stakeholders and the general public is to develop the necessary cornerstone of trust (see suggestion sketched in Figure 8.1). This human relations issue is fundamental to the success of the Wellington/Guelph waste management master planning process. In addition, the author is convinced that all parties are committed to achieving the best possible environmental plan for their area, one

which includes sharing the responsibility equally between the participants. Therefore, it is possible, with the necessary commitment from all sides, that a plan can be developed to achieve the community objectives.

8.4.2 Directives for constructive citizen participation in waste management issues

Some basic rules for citizen participation and joint planning, to get the best results for both the citizens, the politicians and the planners, are as follows:

The first important rule in planning for waste management, that can be applied to any planning process, is that the decision to plan for waste has to be completely and thoroughly understood by the entire community. The second is that the process being used has to be agreed upon at the outset. It's simply no good to start looking for hard-tech solutions to waste management, if the taxpayers want the emphasis to be on soft-tech solutions such as resource recovery. The objective for the project must be set at the outset. Determine what the plan is trying to achieve and how it will achieve it. There should be no assumptions at the outset on the technology to be used, or the sites.

Once the process is agreed, the technical, social and environmental work can begin, properly staged, with adequate time for citizens to contribute their ideas - all the way along.

Step 1: The first step is to define and agree that there is a problem.

Step 2: Define and agree on the objective of the Plan.

Step 3: Review all alternatives to achieve the objective, publicly.

Step 4: Determine and agree on the best alternative(s) to achieve the objective.

Step 5: Decide how and where the sites for the facilities will be located. Reach agreement in principle.

Step 6: Approach landowners personally and discuss the process, the approach, the objective, and the steps taken to achieve the objective.

Step 7: Draw on the strength developed in the community to aid neighbouring and affected landowners and municipalities in determining the best way to mitigate the effects. Have the citizens who have worked on the study all along work with the affected residents. Show that the community cares and will look after the interests of those affected.

Step 8: Encourage landowners to collect data in the field to help evaluate the environmental conditions of the site. Use their studies, their data, their ideas.

Step 9: Complete the plan.

Following the basic rules discussed earlier, and knowing where and when to get help in the process, any project can be enhanced by NIMBY. Exploring ideas with people, from the beginning provides an enormous, free resource to planners, and technical people.

There is no need to fear the public. Many businessmen sit in their offices and dread going out to meet with people in public fora. One can't blame them, if the forum resembles a blood sport. Facing 1,000 angry citizens challenging your credibility is not an easy task - so why create the circumstance in the first place? It is futile to hold a public meeting if 1,000 people will show up intending only to lynch the proponent.

Talk to the people all the way along. Put together workshops, round tables, think tanks. It's not mandatory to hold a public meeting. There are other, more civilized ways of obtaining public input. The methods used should depend upon the stage of the plan.

Time and time again, planners complain they had public meetings in the first stages of a proposal and no one showed up. Of course no one showed up, because very few people take note of an ad in the paper to discuss planning matters. Community networking is required at the outset. The proponent should determine who lives in the community, who are the activists, what have been the issues in the past, who was involved, be pro-active; it takes a long time to get people interested. Do not leave the public alone until it's too late for them to make a valid contribution to the plan - by then, it's almost too late to harness their energy and benefit from their creative ideas.

Sometimes proponents or consultants are too close to the project to be effective. They are seen, naturally enough, to be on the payroll and not truly objective. It is important sometimes when NIMBY surfaces to identify an independent individual, who is not aligned with any of the parties - who is respected and agreeable to all parties - to conduct the discussions. Sometimes it is necessary for this individual to conduct fact-finding exercises - visiting stakeholders to determine their position.

Once this has been done, the parties must be brought together. It is only through the complete and thorough understanding of each viewpoint and need, that the community can work together to achieve the objective.

Municipal and provincial government projects are easier than private ones in the author's experience. But private projects are not impossible if the proponent is sincerely interested in listening and appreciating the other parties' viewpoints.

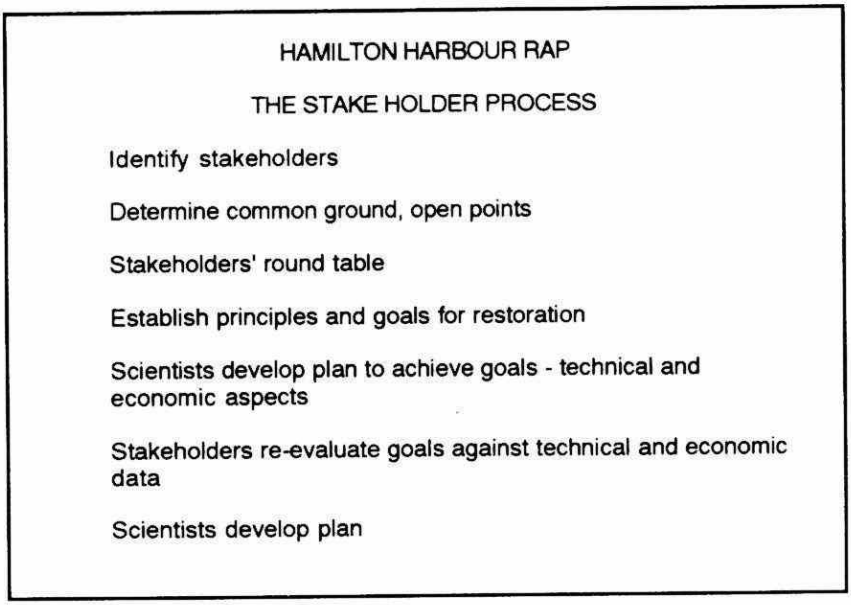
8.5 AN EXAMPLE OF STAKEHOLDER INVOLVEMENT FROM THE OUTSET - HAMILTON HARBOUR RAP.

Another example of citizen involvement in Ontario is the Remedial Action Plan (RAP), e.g. Hamilton Harbour's RAP. A summary sketch of this process is given in Figure 8.2.

Hamilton Harbour is located in the industrialized heartland of southern Ontario in an area known as the Golden Horseshoe. The harbour is home to the largest iron and steel industry in Canada. The area is beautifully scenic - with the natural heritage resource of the Niagara Escarpment cutting across the Region, fondly known as the Mountain.

Since the start of the century, the harbour has served as a containment basin for industrial and municipal discharges. It supported a major commercial fishery - which has long since ceased. Swimming was permitted until the 1930s. In the early '80s the harbour water was given an 'A' grade - which according to Alderman G. Copps was the only time Hamilton has not been proud of such a high rating.

Figure 8.2 Hamilton Harbour, the Stakeholder Process


HAMILTON HARBOUR RAP
THE STAKE HOLDER PROCESS
Identify stakeholders
Determine common ground, open points
Stakeholders' round table
Establish principles and goals for restoration
Scientists develop plan to achieve goals - technical and economic aspects
Stakeholders re-evaluate goals against technical and economic data
Scientists develop plan

Traditionally, Hamilton residents have turned their backs on the Bay - the view was widely held that degradation of the Bay was necessary if growth was to continue. As city residents became wealthier, they moved up to the more aesthetically pleasing residential areas on the mountain.

But memories are not short - we are reminded that the Bay used to be named Macassa, a sparkling, pristine environment of great natural beauty.

Residents, industry, labour, politicians and managers alike, were determined in the late seventies to restore the Harbour's beneficial uses, but there was no clear organizational framework through which they could jointly discuss, agree and most importantly, achieve their goals - many of which were substantially different.

The International Joint Commission's Water Quality Board provided the momentum and organizational framework that had been missing for decades, through the water quality restoration programs known as remedial action plans.

There are over a dozen different agencies responsible for water quality, uses, controls and development of the water body and the watershed. Seven municipalities, functioning under the auspices of two regional governments, complement these agencies.

The weighing of industrial and commercial uses against the interests of environmentalists was debated through the media. There was no clear framework for resolving disputes. Single issues which affected the harbour were reviewed in isolation. The presence of a laudable ecosystem strategy was clearly lacking.

So in 1986, the governments of Canada and Ontario provided the following framework:

- a RAP program established,
- funding for substantial community involvement was provided,
- the program incorporated the spirit of the RAP process, viz community support in the development of the RAP is essential if the RAP is to be implemented,
- way before a complete environmental assessment of the harbour was available - an integrated approach to RAP development was established between the key players:

  the technical advisors (writing team)

  the implementation/user groups (stakeholders)

  the general public.

The first two groups began, at the outset, to develop a joint decision making process and the third group, the general public, participates as a source of sound original ideas and as a barometer of the acceptability of the stakeholder/writing team's goals and recommendations.

To start the process, the governments contracted a project facilitator to interview each possible "stakeholder". Stakeholders include agencies, organizations, institutions, government bodies, industries, commerce and private citizen groups who make use of, wish to make use of, or in some manner have jurisdiction over the use of the harbour water. Over 60 interviews were held - from which a

diverse group of 49 participants to the plan emerged all with one common objective:

"To pursue and develop areas of common ground between stakeholders; to narrow areas of difference; and to develop input to a remedial action plan for Hamilton Harbour water quality which may achieve IJC water quality objectives."

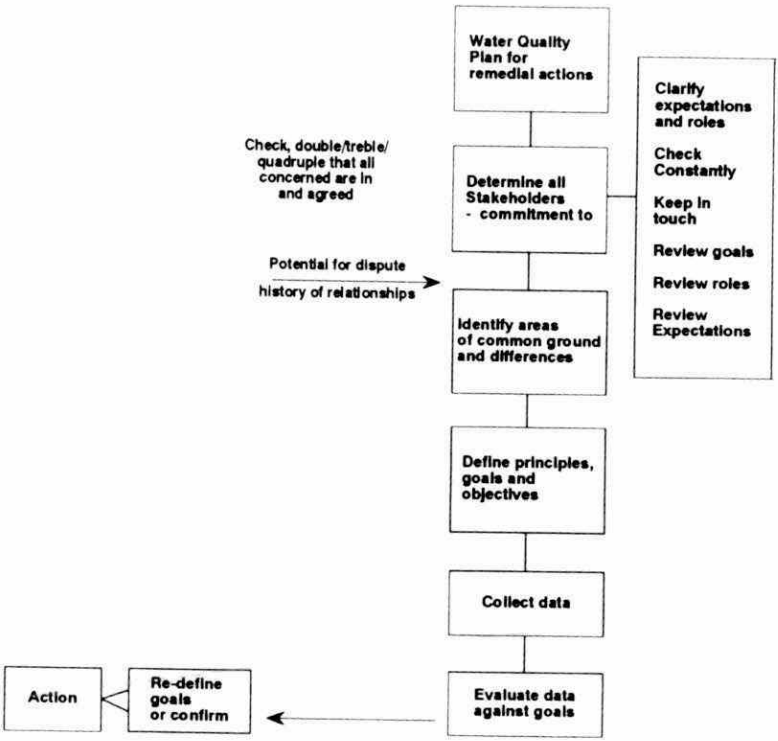
Those making this commitment included the two senior governments, industry, seven municipalities, recreation and shipping interests, commerce, and environmentalists. Stakeholders quickly formed an organization of sorts - establishing use goals and testing those goals on their constituent groups and the general public. They issued two reports - the first sets the general foundations upon which the RAP can be built and includes remedial actions. The second updates their general goal statements and recommends ways to incorporate land use planning considerations and plans in progress.

The current and desired use goals identified by stakeholders include:

recreational boating
body contact sports
swimming
fisheries - re-establish a naturally reproducing edible self - sustaining warm water fisheries
shipping and navigation
industrial water intake and discharge
wildlife habitat
recipient of acceptable effluent
an education resource

You can see by this ambitious list the potential for substantial conflict. There is recognition that not all of the uses can be continued or restored *throughout the total harbour.* Stakeholders have suggested areas where swimming could be restored, providing that no conflicting use (such as industry) is permitted in that area.

Figure 8.3 Joint Planning Approach



After the use goals were defined, individual stakeholders issued formal responses and renewed their commitment to the RAP process and the goals. A set of general overriding principles were established:

the ecosystem principle - which gives equal weight to and integrates social, economic and environmental considerations;

the philosophy of zero-discharge;

the need for public acceptance and support through public access; and

the need for aesthetic enhancements.

The Hamilton Harbour RAP has not been a simple task for stakeholders to negotiate compromises. The 49 people, who regularly sit around the same table express frequent frustration but are optimistic. The meetings resemble a tug of war - with healthy and stimulating debate. It is the author's view that the experiences at these meetings are good exercises for the more difficult decisions ahead.

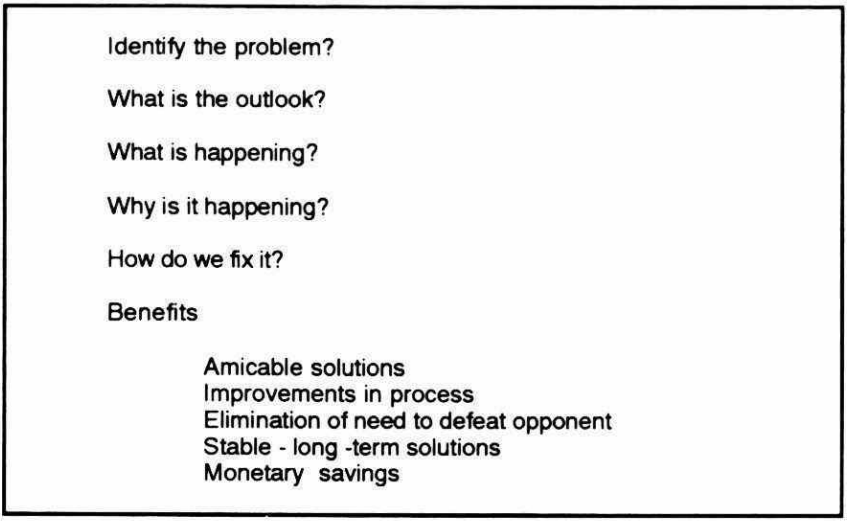
The stakeholders and the writing team are tackling the task enthusiastically, together. The commitment of all involved - the governments, their staff, the writing team and the stakeholders - is an essential element to the RAP's success.

On the group are the implementers, politicians and influential citizen leaders. They have the authority to negotiate an implementation strategy for the plan.

8.6 SUMMARY

In summary, there are many different ways to involve the public, and never enough time or money to do it. The thesis here is that a project can only benefit from citizen involvement - because it's their community, their money and their future. Since more and more planning processes are subject to intense scrutiny by the taxpayer,

Figure 8.4 Programs which need a fix: steps to achieve results



flexible and creative ways to harness their energy and resourcefulness must be designed. The process is summarised in Figures 8.3 and 8.4 above.

GLOSSARY OF TERMS

This glossary has been largely abstracted and collated from several MOE reports, two of which were used extensively as background for this book, particularly: *Technical guidelines for preparing a pollution control plan* (MOE, 1987) and *Water management - goals, policies objectives and implementation procedures* (MOE, 1984).

Advanced treatment - process or method for supplementary treatment of sewage and other wastes beyond the quality achieved by conventional secondary treatment.

Application factor - the ratio of the maximum concentration having no negative affect on the test organisms, to the 96 -hour LC50 concentration.

Artificial aeration - a lake management technique used in water bodies with low concentrations of dissolved oxygen to increase dissolved oxygen levels and to improve fish and fish food organism productivity and to reduce anoxic odours.

Assimilative capacity - the ability of a waterbody to transform and/or incorporate substances (e.g. nutrients) by the ecosystem, such that the water quality does not degrade below a predetermined level.

Bioaccumulation - the uptake and retention of contaminants by an organism from its environment.

Bioassay - a determination of a concentration or dose of a given material necessary to affect a test organism under stated conditions.

Biota - the combined fauna and flora of any geographical area or geological period.

Catchment - surface drainage area.

Chemical materials - substances obtained by or used in processes in industry and agriculture; including heavy metals, salts, petroleum products and radio-active wastes.

Cold water fishery - a fresh water, mixed fish population, including some salmonids.

Combined sewer - a sewer intended to carry surface runoff, sewage and industrial wastes allowed by sewer by-laws.

Combined sewer overflow - flow from a combined sewer, in excess of the sewer capacity, that is discharged into a receiving water.

Conservative pollutant - a pollutant that retains one form in the receiving water (e.g. chloride, sodium, phosphorous, etc.).

Cost-effective - providing the optimum effect at the most reasonable cost.

Criterion, Water quality - same as *water quality objective*

Cumulative - brought about or increased in strength by successive additons.

Design storm - a rainfall of specified amount, intensity, duration, pattern over time, and to which a frequency is assigned, used as a design basis.

Dry weather flow - combination of domestic, industrial and commercial wastes found in sanitary sewers during dry weather ; not affected by recent or current rain.

Detention - the slowing, dampening, or attenuating of flows either entering the sewer system or within the sewer system, by temporarily holding the water on a surface area, in a storage basin, or within the sewer itself.

Effluent - the wastewater discharged to a receiving water body following sewage treatment and/or industrial processing.

Erosion - the processes by which the ground surface is worn away by the action of wind and water; also the process by which the bed and banks of a stream collapse and/or are worn away by the action of water.

Equalization - the averaging (or method for averaging) of variations in flow and composition of a liquid.

Eutrophication - the progressive enrichment of surface waters, particularly nonflowing bodies of water such as lakes and ponds, with dissolved nutrients, such as phosphorus and nitrogen compounds, which accelerate the growth of algae and higher forms of plant life and result in the utilization of the usable oxygen content of the waters at the expense of other aquatic life forms.

Exfiltration - the escape of water from a water main or sewage from a sewer, into subsurface materials due to a break, leaks, etc., in the pipe; also the flow of groundwater into ditches and channels.

Fauna - the animals living within a given area or environment or during a stated period.

Flora - the aggregate of plants growing in and usually peculiar to a particular region or period.

First flush - the condition, often occurring in storm sewer discharges and combined sewer overflows, in which an unusually high pollution load is carried in the first portion of the discharge or overflow.

Flood plain - the area of ground along a stream course that is covered by water at flood stage.

Forested areas - includes those regions of the basin where the dominant activity is directed towards the continued lifecycle of trees both deciduous and coniferous.

Foundation drain - a pipe or series of pipes that collects water drained from the foundation or footing of structures and discharges these waters into sanitary, combined or storm sewers or to other points of disposal, for the purpose of draining unwanted waters away from such structures.

Geometric mean - the antilog of the mean of the log transformed data.

Guideline - any suggestion, rule, etc., that guides or directs.

Goal - an aim or objective towards which to strive; it may represent an ideal condition that is difficult, if not impossible to attain economically.

Hazardous substances - chemicals considered to be a threat to man in the environment, including substances which (individually or in combination with other substances) can cause death, disease including cancer, behavioral abnormalities, genetic mutations, physiological malfunctions or physical deformities

Hypolimnion - the region of a body of water extending below the thermocline to the bottom of the lake and thus removed from much of the surface influence.

Infiltration - the seepage in dry or wet weather or both of groundwater or vadose water into any sewer (storm, sanitary, combined). Generally, infiltration enters through cracked pipes, poor pipe joints or cracked or poorly jointed manholes; also the loss of surface runoff into pervious ground.

Inflow-infiltration (I/I) - Inflow is defined as the gross influx of wet weather flows into a sanitary sewer. Sources of inflow include roof leaders, cross-connections (storm to sanitary) and directly connected catch basins.

Lethal - involving a stimulus or effect causing death directly.

Liquid waste disposal - the application of municipal and industrial wastewater effluents such as sewage sludge, industrial effluents and sludges and wastewaters from individual home waste treatment systems to land.

Major system - the route followed by storm runoff when the minor system is either inoperative or inadequate. It generally should consist of roads and major drainage channels.

Median lethal concentration (LC50) - the concentration of a test material that causes death to 50 per cent of a population within a given time period.

Micrograms per litre - (ug/l) and milligrams per litre (mg/l) - units of measure expressing the concentration of a substance in a solution.

Minor system - the drainage pipes, roadway gutters, enclosed conduits, and roof leader connections designed to convey runoff from frequent, less intense storms, to eliminate or minimize inconvenience in the area to be developed.

Mixing zone - an area of water contiguous to a point source, where exceptions to water quality objectives and conditions otherwise applicable to the receiving water, may be granted.

Non-conservative pollutant - a pollutant that can exist in more than one form (e.g. nitrogen, BOD_5, etc.).

Non-point source - an area from which pollutants are exported in a manner not compatible with practical means of pollutant removal (e.g. crop lands).

Nutrients - for the purpose of this book, this term is restricted to a description of the primary nutrients, nitrogen and phosphorus.

Objective, Water quality - a designated concentration of a constituent, based on scientific judgements, that, when not exceeded will protect an organism, a community of organisms, or a prescribed water use with an adequate degree of safety.

Pesticides - an agent (usually a chemical) used to destroy or inhibit undesirable plants, fungi, animals (vertebrate and invertebrate) and bacteria.

Physical-chemical treatment process - means of treatment in which the removal of pollutants is brought about primarily by chemical clarification in conjunction with physical processes.

Pollutant - dredged soil, solid waste, incinerator residue, sewage, garbage, sludge, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, dirt and industrial, municipal and agricultrual waste discharged into water.

Primary treatment - process or methods that serve as the first stage treatment of sewage and other wastes, intended to remove suspended and settleable solids by gravity and sedimentation. It provides no changes in dissolved and collodial matter in the sewage or waste flow.

Rational method - coarse means of estimating storm drainage flow rates using formula Q = CIA, where C is a coefficient describing the proportion of rainfall expected to run off based on the physical characteristics of the drainage area, I is the rainfall intensity, and A is the area. (It has no valid basis - editor's note).

Recreational areas - the use of land and water resources for rest, relaxation and recuperation, including a variety of sports and other activities on public and private lands so designated for that purpose; including parks, cottage subdivisions, high-density, nonsewered residential areas, intensive recreational land use, ski slopes and recreational beaches.

Regulation - a specific law that legally applies in all relevant situations.

Reserve capacity - a portion of the assimilative capacity of a stream, which is set aside to provide an adequate margin of protection, including consideration for future water uses.

Retention - the prevention of runoff from entering the sewer system by storing on a surface area or in a storage basin.

Roof leader - a drain or pipe that conducts storm water from the roof of a structure, downward and into a sewer for removal from the property, or onto or into the ground for disposal by seepage.

Runoff - that portion of the precipitation on a drainage area that is discharged from the area into stream channels.

Runoff coefficient - fraction of total rainfall that appears as total runoff volume after subtracting depression storage and interception. Typically supposed to account for infiltration into ground and evaporation.

Sanitary sewer - a sewer that carries liquid and water-borne wastes from residences, commercial buildings, industrial plants, and institutions, together with relatively low quantities of ground, storm, and surface waters that are not admitted intentionally.

Secondary treatment - processes or methods for the supplemental treatment of sewage and other wastes, usually following primary treatment, to effect additional improvement in the quality of the treated wastes by biological means of various types.

Sediment - soils or other surface materials transported by wind or water as a result of erosion.

Sedimentation - the process of subsidence and deposition of suspended matter carried by water, sewage, or other liquids, by gravity.

Sewershed - the area of a municipality served by a given sewer network. For example, the area tributary to a given combined sewer overflow or a given WPCP would be termed the sewershed tributory to the overflow or WPCP.

Simulation - representation of physical systems and phenomena by mathematical models.

Solid waste disposal - the disposal of municipal solid waste from residential, commercial and industrial activities, either in sanitary landfill sites or in other forms of disposal.

Storm sewer - a sewer that carries storm water and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes.

Storm sewer discharge - flow from a storm sewer that is discharged into a receiving water.

Stormwater - water resulting from precipitation which either percolates into the soil, runs off freely from the surface, or is captured by storm sewer, combined sewer, and to a limited degree, sanitary sewer facilities.

Sub-lethal - involving a stimulus below the level that causes death.

Surcharge - the flow condition occurring in closed conduits when the sewer is pressurized or the hydraulic grade line is above the crown of the sewer.

Synergism - interactions of two or more substances or organisms producing a result such that the total effect is greater than the sum of the individual effects.

Tertiary treatment - same meaning as advanced treatment.

Transportation - the movement of people and goods for social and economic purposes involving the use of machines or equipment including highways and roads, railroads, airports and utility corridors (transmission lines, pipelines).

Urban drainage or urban drainage system - includes both man-made and natural elements. An urban drainage network usually consists of two separate systems: sanitary and storm sewers.

Urbanized area - central city, or cities, and surrounding closely settled territory. Central city (cities) have populations of 50,000 or more. Peripheral areas with a population density of one person per acre or more are included (United States city definition).

Urban runoff - surface runoff from an urban drainage area that reaches a stream or other body of water or a sewer.

Warm water fishery - a fresh water, mixed fish population with no salmonids.

Waste - for our purposes, waste means any solid, liquid, gas, odour, heat, sound, vibration, radiation or combination of any of these resulting directly or indirectly from the activities of man which may: impair the quality of the natural environment for any use that can be made of it; cause injury or damage to property or to plant or animal life; cause harm or material discomfort to any person; adversely affect the health or impair the safety of any person; or render any property or plant or animal life unfit for use by man.

Watershed - the region drained by or contributing water to a stream, lake, or other body or water.

Water table - the upper level of the free groundwater in a zone of saturation, except when separated from underlying groundwater by unsaturated material.

Water treatment/water purification - the processes or method by which "raw" water is treated to remove bacteria, and possible algae, colour, suspended material or other impurities in order to meet the minimum water quality objectives for human consumption.

Weed harvesting - the mechanical cutting of aquatic macrophytes and subsequent removal of the detritus from the water body.

Wet weather flow - a combination of dry weather flows, infiltration and inflow which occurs as a result of rain and storms.

Zone of passage - in river systems, reservoirs, lakes, estuaries and coastal waters, zones of passage are continuous water routes of sufficient volume, area, and quality to allow passage of free-swimming and drifting organisms so that no significant effects are produced on the populations.

KEY TO ABBREVIATIONS

Many expressions recur frequently in the text, and where helpful, abbreviations are substituted. Typical examples are well-known acronyms, names of computer programs, pollutants or chemical terms, variables and trade names. In some cases further explanations are included in the Glossary of Terms.

ACRONYMS

AES	Atmospheric Environment Service
ASCE	American Society of Civil Engineers
BAT	Best Available Technology
CCIW	Canada Centre for Inland Waters
CSO	Combined Sewer Overflow
DWF	Dry Weather Flow
EA	Environmental Assessment
EFW	Energy from Waste
EMC	Event Mean Concentration
EMPPL	Effluent Monitoring Priority Pollutant List
EPA	Environmental Protection Agency (US)
IJC	International Joint Commission
MEA	Municipal Engineering Association
MISA	Municipal-Industrial Strategy for Abatement
MNR	Ministry of Natural Resources
MOE	Ministry of the Environment
MOH	Medical Officer of Health
MSP	Monitoring and Sampling Program
MWCOG	Metropolitan Washington Council of Governments
NIMBY	Not In My Backyard
NURP	National Urban Runoff Program (US)
NWS	National Weather Service
PAC	Public Advisory Committee
PCP	Pollution Control Plan
PPEC	Provincial Project Evaluation Committee
PR	Public Relations
PWQO	Provincial Water Quality Objectives
RAP	Remedial Action Plan
RFP	Request for Proposal

ABBREVIATIONS

SCAPCP	St. Catharines Area Pollution Control Plan
STP	Sewage Treatment Plant
TAWMS	Toronto Area Watershed Management Strategic Study
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WPCP	Water Pollution Control Plant
WWF	Wet Weather Flow
WWTP	Waste Water Treatment Plant

COMPUTER PROGRAMS

CREAMS	Chemicals Runoff and Erosion from Agricultural Management Systems
EXAMS	Exposure Analysis Modelling System
GAMES	Guelph Agricultural Model for Erosion and Sedimentation
HSPF	Hydrological Simulation Program Fortran
SIMS	Sewer Inventory Maintenance System
STORM	Storage and Treatment Overflow and Runoff Model
SWMM	Storm Water Management Model
WIMS	Water Inventory Maintenance System

POLLUTANTS

BOD_5	Biological Oxygen Demand at 5 Days
DD	Dust and Dirt
DDT	Dichlorodiphenyltrichloroethane (organic pesticide)
DO	Dissolved Oxygen
FC/FCOLI	Fecal Coliforms
NO_3N	Nitrate Nitrogen
PAHs	Polycyclic Aromatic Hydrocarbons
PBB	Polybrominated Biphenyl
PCB	Polychlorinated Biphenyl
pH	Measure of acidity/alkalinity
PERC	Perchloroethylene (dry cleaning solvent)
SS	Suspended Solids
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TOD	Total Oxygen Demand
TSS	Total Settleable Solids

SUBJECT INDEX

Editor's note: This index is unfortunately not exhaustive and should be used only as a first guide to finding the required reference.

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